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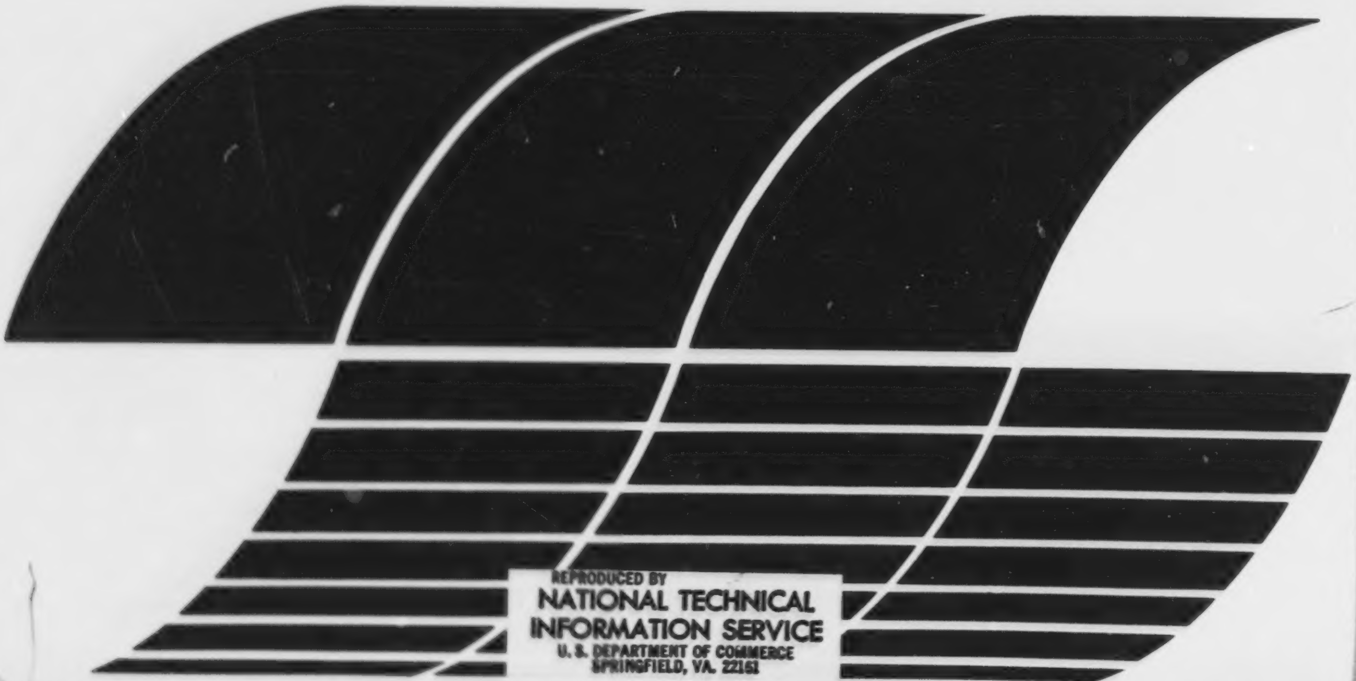

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16. ABSTRACT

This report is an integrated summary of various elements of Phase I of the Ohio River Basin Energy Study (ORBES) which includes three parallel but independent preliminary technology assessments and a number of in-depth topical studies. ORBES Phase I was conducted by research faculty from six state universities in the state comprising the Phase I study region: all of Kentucky, and substantial portions of Illinois, Indiana and Ohio. The results reported are preliminary in nature and reflect limitations in data availability and analysis which were found.

Four alternative scenarios for energy development in the region through the year 2000 were employed to conduct the analysis. Some of the major preliminary fundings of this first year assessment are: (1) air quality limitations in the region are becoming increasingly important considerations; (2) water availability limitations may become important before the year 2000; and (3) a high rate of growth may be associated with an insufficiency of skilled labor to construct conversion facilities. The implications of these and other selected findings for public policy development are discussed.

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a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Ecology Environments Earth Atmosphere Environmental Engineering Geography Hydrology, Limnology Combustion Energy Conversion Materials Handling Other:	Control Technology: Energy Extraction Flue Gas Cleaning Direct Combustion Synthetic Fuels Nuclear Thermal Improved Efficiency Advanced Systems Other Processes & Effects: Transport Processes Ecological Effects Health Effects Integrated Assessment Energy Cycle: Extraction Processing Conversion Utilization Fuel: Coal Oil Gas Nuclear Solar Waste as Fuel Hydroelectric Multi-fuel (2 or more)	6F 8A 8F 8H 10A 10B 48 A-F 13B 97 A-H

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OHIO RIVER BASIN ENERGY STUDY
ORBES PHASE I: INTERIM FINDINGS

by

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Grant Number R804848-01

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FOREWORD

Development of our Nation's energy resources has, and will have, massive effects on our economy, society and environment. These effects must be identified and understood if energy development is to be undertaken with proper concern for the interests of all parties affected. As planner and coordinator of the 18-agency federal Interagency Energy/Environment Research and Development Program, the U.S. Environmental Protection Agency is responsible for programs that range from the analysis of health and environmental effects of energy systems to the development of environmental control technologies. A part of this interagency effort is the Integrated Assessment Program. Its mission is two-fold: to identify and analyze the environmental consequences of the entire range of industrial activities connected with available and anticipated energy development technologies, and to evaluate the environmental, socioeconomic, and institutional effects associated with impending energy development activities. Several projects are underway to accomplish these objectives within specific geographical regions where energy development is expected to intensify.

Similar aims are held, in part, by a group of environmentally aware citizens who, in the early 1970s, became concerned with plans for accelerated power plant development along the Ohio River. They and other Ohio River Basin residents sought information on the effects that energy development could have on their environment. These effects include not only the obvious physical ones on air, land, and water quality, as well as those on public health, but also less easily measurable economic and social effects. The availability of this kind of information to public and private policymakers and interested citizens will support knowledgeable and reasonable decisions about the region's energy and environmental future.

The Ohio River Basin Energy Study (ORBES), the first year of which is reported here, originated from concerns of citizens within the basin. In this spirit, the study attempts to carry out research with the maximum degree of public input. Interaction between project researchers and members of the public is sought as the study progresses. The objective of this continuing feedback is to ensure that the researchers consider those issues of greatest concern to the interested parties.

In one sense, ORBES is an experiment in communications, carried out in various ways--a Project Advisory Committee drawn from groups expected to be affected by regional energy development, a newsletter reaching several thousand subscribers in the study region, a series of public forums presenting preliminary research results, and written reports which discuss specialized topics and broad areas of research findings--all combined within an open study process. Written reports are one such communication device. Communication efforts such as this one are essential to the citizen who wishes to gain a full comprehension of the consequences of future energy development within the Ohio River Basin.

During the first year of ORBES (Phase I), relevant energy use and environmental management alternatives were identified, and a range of emerging policy issues was articulated. Potential solutions to some problems raised by regional energy development were put forward. During Phase II, now in progress, in-depth analyses are being made of the issues identified in Phase I, as well as of new issues identified as the study progresses. The methods of communication used in Phase I are being employed as a continuing activity to solicit perceptions of interested parties concerning the relative importance of identifiable energy and environmental issues and of policy options to deal with them. Comments on this report will be valuable to the project's managers and researchers. In turn, the project's results will provide parties-at-interest with information on the effects that alternative energy decisions could have on the future of the Ohio River Basin.

This report would not have been possible without the combined efforts of the Phase I researchers. I wish to express my personal appreciation to each of them, and especially to the authors of this report, Jim Stukel and Boyd Keenan, as ably assisted by Stephanie Kaylin and Jenifer Robison. They succeeded in their difficult task of integrating several thousand pages of project reports and other materials into the short, comprehensible document that you hold in your hand. I trust that this volume will serve as a useful prologue to the full analysis of energy development effects within the basin that will be published at the completion of the study.

Lowell Smith

Lowell Smith, Project Officer
Office of Energy, Minerals and Industry
Office of Research and Development

PREFACE

This publication is an interim report that attempts to summarize the first year of a multiuniversity activity known as the Ohio River Basin Energy Study (ORBES). The overall study objective is to assess potential environmental, social, and economic impacts of proposed power plants and other energy conversion facilities on a major portion of the Ohio River Basin. Funding for the project is being provided through grants from the U.S. Environmental Protection Agency (EPA) to the universities involved.

The institutions receiving grants during Phase I of ORBES were Indiana University, the University of Kentucky, the University of Louisville, the Ohio State University, Purdue University, and the University of Illinois (both the Chicago Circle and the Urbana-Champaign campuses). Details on the arrangements through which these six universities cooperated during the initial year of the study (1976-1977) are given in Appendix A of this volume.

Concerns of residents in the Ohio River Basin prompted Congress and EPA to support the project. This document and the more detailed reports that accompany it (listed in Appendix B) should be viewed as an interim progress report to these citizens and the general public. Since the public has little interest in specialized jargon, we have attempted to avoid technical language except in cases where it is necessary to convey accurate meaning with respect to possible impacts from energy developments. In the examination of technological problems, however, systematic approaches must be devised. These approaches sometimes require use of a "shorthand" vocabulary familiar to specialists who will judge the work.

EPA's Office of Research and Development, which administers the grants for ORBES, contracted with the Program of Policy Studies in Science and Technology, George Washington University, to prepare a work plan for the project. With minor modifications, this work plan determined the structure and assessment approach for the first year of the study (Phase I). ORBES was cast in the general form of a technology assessment as part of the EPA-administered Interagency Energy/Environment Research and Development Program. A usual practice in this mode of inquiry is to develop scenarios which assume certain conditions and permit researchers to pursue such problems as energy development in a "what if" context. Because so many uncertainties are always present in assessing the future of such problem areas, a scenario should be viewed as plausible, but yet hypothetical. This does not imply, however, that researchers are avoiding reality within the constraints of the selected hypothetical future. In the first year of ORBES, the researchers selected basic high-energy-growth and low-energy-growth scenarios previously developed at the national level in other recent studies.

Under the work plan, technology assessment personnel were organized into three separate university teams for Phase I of the ORBES effort. Independent preliminary assessments were made of possible impacts on the study region. These assessments have been published as separate documents. Consistent with a congressional mandate, the first-year assessments dealt with portions of four states--Illinois, Indiana, Kentucky, and Ohio--in the lower Ohio River Basin. (The ORBES study region for Phase II, which began on November 1, 1977, and is expected to last two years, has been expanded to include virtually all of West Virginia and the southwestern part of Pennsylvania.)

For the first year, EPA also commissioned certain university researchers from the same six universities to produce 10 special studies. These researchers performed in-depth analyses in areas requiring more detailed exploration than was possible by the preliminary assessment teams.

Thus, this interim summary report is an effort to integrate selected findings of the ORBES Phase I report series into a relatively brief document. It was necessary to use our own professional judgments when reconciling differences in perspective or emphasis among the reports of the three independent teams. In preparing the report, we have exercised prerogatives as co-directors for the ORBES Experimental Management Plan under our own EPA grant. When appropriate we have consulted non-ORBES findings available from other EPA-sponsored research and from outside sources. It should be noted that several major environmental laws were passed by Congress after most of the Phase I analysis was completed. These pieces of legislation are the Surface Mining Recovery and Control Act, the Clean Air Act Amendments of 1977, and the Clean Water Act Amendments of 1977. They will be taken into account during ORBES Phase II.

We are indebted to all ORBES researchers for contributions which have made it possible to complete Phase I. These researchers are listed in Appendix C. In particular, the assistance of the three preliminary assessment team leaders has been invaluable. They are Robert E. Bailey, formerly of Purdue University and now at The Ohio State University; Hugh T. Spencer, University of Louisville; and Ross J. Martin, University of Illinois at Urbana-Champaign. They cannot be held responsible, however, for the contents of this summary report, the selection of certain illustrative findings and the omission of others, or the interpretations applied to the findings.

Not all impacts identified by ORBES researchers could be included in this report. We encourage the reader to pursue particular interests in the reports of the three preliminary assessments and the 10 special studies. Here we have concentrated on a *comparison* between the basic low- and high-energy-growth options as projected for the year 2000.

Early attention by the reader to the overall report format is desirable. The first chapter summarizes Phase I findings. The ORBES study background and the development of scenarios are then reviewed, followed by comparisons between scenarios in four basic areas: impacts on natural resources; impacts on developed resources; impacts on the biological and ecological environment; and public health, economic, and social impacts.

It should be emphasized that this interim document is a progress report of ORBES research to date. Even before the study was initiated, congressional representatives indicated that one of its major purposes would be to stimulate a new dialogue among all affected parties. They also expressed the hope that the study would help begin a process through which the region's concerned citizens would be provided information and concepts to aid them in communicating with government agencies and public utilities. In an attempt to be responsive to these expectations, illustrative public policy issues, framed as questions, are included at the end of appropriate chapters in this report.

We recognize that we have not been entirely comprehensive in identifying policy issues arising from the interim findings. We also appreciate the sincerity and candor of several reviewers of this report in draft form, who have questioned the value or propriety of including such policy issues. But for the reasons cited, we must respectfully decline to follow their counsel to delete the listings. In reviewing our report, the reader is encouraged to add to these issues and to make the additions known to us. A major purpose in cataloging such issues is to assure that they will be addressed more definitively during the second phase of the project.

Another point of difference during ORBES Phase I had to do with the assumptions implicit in the development of scenarios, particularly in areas of health and safety as related to nuclear-fueled facilities. The continuing debate on these facilities among respected and responsible scientific authorities remains unresolved. As a consequence, some of the researchers on the University of Kentucky-University of Louisville preliminary assessment team expressed concern over tacit scenario assumptions in this area. A statement of such concern by a philosophy of science professor is given below:

> The most serious logical fallacy underlying the ORBES conclusions is the "argument from ignorance." Team researchers have admitted both that long-term health effects (for example, carcinogens from low-level radiation) of certain energy scenarios are unknown and that current government standards for various pollutants have not been tested adequately, yet these very standards have been used to evaluate various energy strategies. In thus arguing from ignorance, researchers have inadvertently addressed what we are technologically able to do, but neither what it is logically valid to do nor what we ethically ought to do.

It is anticipated that in ORBES Phase II the nuclear issue will be addressed more adequately than was possible in the Phase I assessment. The authors recognize that there are many unresolved questions but are not in total agreement with the statement quoted above. It is their intent, and one of the purposes of the ORBES study, to be responsive to any and all viewpoints on these subjects.

The cooperation of the EPA project officer for ORBES, Lowell Smith, is gratefully acknowledged. He offered counsel freely, but his advice was totally consistent with the conditions of our grant which assured independence as university researchers. Neither he nor other EPA personnel made any attempt to exert untoward influence in the preparation of this report.

Prominent among EPA staff who provided assistance were James H. Phillips of Region V offices in Chicago, Illinois, and Walton W. Jones of Region IV, Atlanta, Georgia.

An ORBES Advisory Committee with representation from major public and private sectors affected by energy developments was appointed early in Phase I, and additions were made throughout the year. A list of Advisory Committee members as of November 1, 1977, appears in Appendix D. Committee members were invited to provide comments on the three preliminary assessments and the special studies. A number of their responses were helpful in the development of this integrated summary report. However, a listing of the committee roster should not be construed as endorsement of this summary or any publication in the ORBES series by any member. Comments on the various reports were varied, ranging from supportive to extremely critical. All committee members, as well as university researchers, were given an opportunity to respond to a draft of this summary. We are grateful for those comments received. Such responses are being published separately as Volume IV of the ORBES Phase I report series.

Research and editorial staff support for the preparation of this report was provided most ably by Stephanie L. Kaylin, ORBES staff associate, and A. Jenifer Robison, ORBES research associate. Ms. Kaylin was responsible for overall coordination and worked specifically on chapters 1 through 4 and the appendices, while Ms. Robison worked on chapters 5 and 6.

We alone are responsible for the contents of this integrated summary report.

James J. Stukel

Boyd R. Keenan

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CHAPTER 1

SUMMARY

During Phase I of the Ohio River Basin Energy Study (ORBES) two basic energy-growth options were analyzed. The objective was to make a tentative identification of potential environmental, social, and economic impacts that might result from varying levels of electrical energy facility development in the study region; more definitive results are expected from the second phase of the project. The Phase I ORBES region consisted of all of Kentucky and substantial portions of Illinois, Indiana, and Ohio.

The high-energy-growth option calls for an average annual electrical energy growth rate of 5.4 percent between 1975 and 2000, the time span of the study. Under the low-energy-growth option, the average annual rate is 2.8 percent. The major difference between the national forecasts from which these two regional-level energy-growth options were adapted lies in the energy sector of the economy. The high-energy-growth option takes an essentially "business as usual" approach, with present trends projected into the future. The low-energy-growth option, on the other hand, assumes that energy conservation measures will lessen demand for electrical energy, resulting in a decreased growth rate in energy conversion facilities. This energy-growth option also assumes, however, that there will be an increased growth rate in certain industrial sectors sufficient to maintain gross national product at a level comparable to that of the high-energy-growth option. Each energy-growth option was further broken down into two scenarios, each with a different "mix" of coal-fired and nuclear-fueled energy conversion facilities.

Unless otherwise noted, the first-year findings listed below are regional in scope and cover the study period 1975-2000.

NATURAL RESOURCES

--The amount of land expected to be converted to urban uses in the ORBES region between 1975 and 2000 is comparable to the amount required under the high-energy-growth option for energy extraction, processing, conversion, and transmission. Under both the high- and the low-energy-growth options, sufficient land would be available for the support of energy conversion facilities.

--Potential land-use conflicts exist between coal mining and crop production, particularly in Illinois, and between coal mining and forest and recreational areas in the Appalachian portions of Kentucky and Ohio. Other potential land-use conflicts exist between power plant sites, on the one hand, and agricultural lands and bottomland flats and other scenic and recreational areas along the Ohio River, on the other.

--Regionwide, there would be a sufficient quantity of water to support the energy conversion facilities associated with both the high- and the low-energy-growth options. In some localities, however, there could be significant water shortages under sustained low-flow conditions.

--If irrigation were to become widespread in the ORBES region in conjunction with the power plants sited under the high-energy-growth option, water shortages could result.

--Under the high-energy-growth option and with widespread use of irrigation, water use requirements could lead to navigational problems on the Ohio and some of its tributaries under sustained low-flow conditions.

--Given the requirements of the high-energy-growth option, under low-flow conditions the region would become extremely dependent on water flowing into it.

--Assuming the use of wet cooling towers, in the year 2000 under the high-energy-growth option consumptive losses of water for power could range to more than twice the amount lost under the low-energy-growth option.

--In 1970 in the ORBES region, municipal and industrial uses of water combined were approximately 13 times as great as the use of water for power-related purposes. In 2000 under the high-energy-growth option, power-related uses could be more than 3 times as great as municipal and industrial uses combined.

--If annual coal requirements level off after the year 2000, there is a sufficient amount of this fuel in the ORBES region to supply regional energy conversion facilities for several hundred years.

--Sufficient limestone would be available to meet projected requirements for new flue-gas desulfurization systems, but sufficient processed lime might not be.

--Nationwide there likely exists sufficient uranium available at prices higher than historic ones to supply nuclear reactors that could be built in the ORBES region through the end of the century. Those plants that could be built in the nation by the year 2000 also probably could be supplied sufficient quantities of this higher cost uranium.

DEVELOPED RESOURCES

--The transport of coal and of industrial supplies and products within the ORBES region would not overly stress the existing regional transportation networks.

--Within the ORBES region under the high-energy-growth option in the year 2000, the industrial sectors that would experience the greatest increases in output would be steel, structural metal products, coal mining, and electric utilities. Nationwide under this option, the sectors that would experience the greatest increases would be industrial patterns, transformers and switchgear, and electric utilities.

--Within the ORBES region under the low-energy-growth option in the year 2000, the industrial sectors that would experience the greatest increases in output would be service industry machinery and household appliances. Nationwide under this option, sectors that would experience the greatest increases would be service industry machinery, household appliances, other stone and clay products (see text), and natural gas.

--Capital investment requirements for electrical energy conversion facilities would range from about $300 billion to $350 billion for the high-energy-growth option to about $50 billion to $70 billion for the low-energy-growth option.

--Nationwide there would be little difference in total employment between the two energy-growth options.

--Employment by electric utilities nationwide in the year 2000 would be 29 percent greater under the high-energy-growth option than under the low-energy-growth option.

--Nationwide under the high-energy-growth option, the industries experiencing the greatest increases in employment relative to the low-energy-growth option would be general industrial machinery, coal mining, and electric utilities. Under the low-energy-growth option, the largest relative increases would occur in service industry machinery; natural gas, water, and sewer services; and household appliances.

--Under one of the high-energy-growth scenarios within the ORBES region, the number of coal-mining workers would increase by approximately two-thirds between 1975 and 2000.

--The high-energy-growth option would require a percentage increase in regional labor supply considerably above national historic averages for the construction and operation of energy-related facilities.

--Between 1986 and 2000, labor requirements for the high-energy-growth option would nearly equal or exceed projected increases in the total number of new workers in the region.

THE ECOLOGICAL AND BIOLOGICAL ENVIRONMENT

--Net regional primary particulate emissions in the year 2000 would decrease approximately 58 percent relative to 1972 emissions under both the low- and high-energy-growth options if all state implementation plans (SIPs) and new source performance standards (NSPS) under the Clean Air Act are met.

--Net regional sulfur oxide emissions in the year 2000 under the high-energy-growth option would increase approximately 7 percent relative to 1972 emissions if all SIP and NSPS standards are met. Under the low-energy-growth option, a decrease of about 1 percent would be expected. This relatively small difference between scenarios is explained by the increased non-energy-conversion industrial activity under the low-energy-growth option.

--Under the low-energy-growth option in the year 2000, regional emissions of sulfur dioxide from the industrial sector would constitute about 35 percent of total emissions of this pollutant (about 50 percent more than emissions from any other sector). To achieve a greater reduction in regional ambient sulfur dioxide concentrations, new control strategies for industrial sources would be required.

--Net regional nitrogen oxide emissions in the year 2000 would increase approximately 90 percent relative to 1972 levels under the high-energy-growth option. Under the low-energy-growth option, the increase would be approximately 68 percent. The increase under both energy-growth options would be accounted for primarily by increased emissions from new coal-fired power plants. Under both options, increased emissions from commercial truck traffic would be significant. Also of importance under the low-energy-growth option would be increases from non-energy-conversion industrial activity.

--Net regional hydrocarbon emissions in the year 2000 would decrease approximately 40 percent and 60 percent relative to 1972 levels under the high-and low-energy-growth options, respectively.

--Levels of secondary particulates formed in the atmosphere from sulfur dioxide and nitrogen oxide have not been quantified, but under both energy-growth options would be expected to increase in concentration. This would reduce visibility and increase haziness. Acid rainfall would be increased in downwind locations.

--Regional and subregional wind corridors exist where, with a build-up of high-emission sources along these corridors, ambient concentration levels for particulate and sulfur oxide emissions might exceed current air quality standards.

--Regional oxygen demand from wastes discharged into the water (BOD and COD) in the year 2000 would be reduced approximately 50 percent relative to 1972 levels under both the high- and low-energy-growth options.

--Under both energy-growth options in the year 2000, total suspended solids discharged from point sources into the waterways of the region would be reduced approximately 98 percent relative to 1972 levels.

--Under the high- and low-energy-growth options, respectively, total dissolved solids discharged from point sources into the waterways of the region in the year 2000 would increase approximately 85 percent and 80 percent relative to 1972 levels. One reason for these rises would be the increases in coal mining projected under the ORBES scenarios.

--If nonpoint sources of water pollution were taken into account, concentrations of both total suspended and total dissolved solids could be noticeably higher than projected under both energy-growth options.

PUBLIC HEALTH, ECONOMIC, AND SOCIAL FACTORS

--Large uncertainties exist as to the number of deaths attributable to the coal fuel cycle versus the nuclear fuel cycle for a given amount of electricity produced. However, most experts agree that under *normal* conditions, the coal fuel cycle is responsible for more premature deaths than is the nuclear fuel cycle.

--Under the high-energy-growth option, the expected number of premature deaths from the coal and nuclear fuel cycles would be more than double the number expected under the low-energy-growth option.

--Current state- and county-level population projections made by various agencies in the ORBES region are contradictory.

--Few locations in the ORBES region have the potential for "boomtown" conditions because of the relatively uniform population density of the region.

--During the development of energy-related facilities, communities with insufficient infrastructures tend to experience social problems. Usually these are small communities in isolated rural areas. Because of problems arising during construction, such communities are slow to reap benefits from the operations phase of facilities.

--Local acceptance of power plant construction varies with actual or anticipated economic benefits to the community. Lack of actual or perceived economic benefits leads to lowered acceptance or increased opposition.

--Regional problems exist in managing energy development and related environmental concerns for which no institutional solutions are currently available.

CHAPTER 2

ORBES BACKGROUND

ORIGIN OF THE STUDY

The 1973-1974 Arab oil embargo and subsequent increases in fuel prices were unprecedented events in the United States. Now, four years later, uncertainty remains as Congress debates President Carter's proposals to handle our energy problems. It is inevitable that some regions of the country will be affected dramatically, regardless of the specifics of any national energy policy that might be adopted.

Such a region is that portion of the United States known generally as the Ohio River Valley. The drainage basin of the Ohio River and its tributaries is an area over 200,000 square miles in size, encompassing portions of 14 states. The river itself flows in a generally southwesterly direction for 981 miles from its beginning at the confluence of the Allegheny and Monongahela rivers at Pittsburgh, Pennsylvania, to Cairo, Illinois, where it empties into the Mississippi.

Interest in the effects of energy development is growing throughout the Ohio River Basin, but within a few months of oil embargo termination in 1974 a variety of social forces focused attention on a section of the basin including portions of Illinois, Indiana, Kentucky, and Ohio. Concern in these four states led a unit of the Congress to direct the U.S. Environmental Protection Agency (EPA) to conduct a study of the potential environmental, social, and economic impacts of the possible concentration of energy conversion facilities in the area. That unit--the Appropriations Committee of the U.S. Senate--particularly requested EPA to consider the potential impacts of coal developments on what the committee called the "lower Ohio River Basin."

Committee intent was interpreted as a study of that portion of the Ohio River main stem and tributaries depicted in Figure 1. This interpretation was based on the committee's use of the term "lower Ohio River Basin" and on its naming of Illinois, Indiana, Kentucky, and Ohio in its request to EPA. Actually, in hydrological terms, the "lower" basin extends south into Tennessee, Mississippi, Alabama, Georgia, North Carolina, and Virginia. Other portions of the middle and upper basin include parts of West Virginia, Virginia, North Carolina, Maryland, Pennsylvania, and New York.

In response to the congressional directive, in late summer 1976 EPA awarded a number of one-year grants to researchers at six universities on seven campuses to undertake specific tasks for a preliminary assessment of

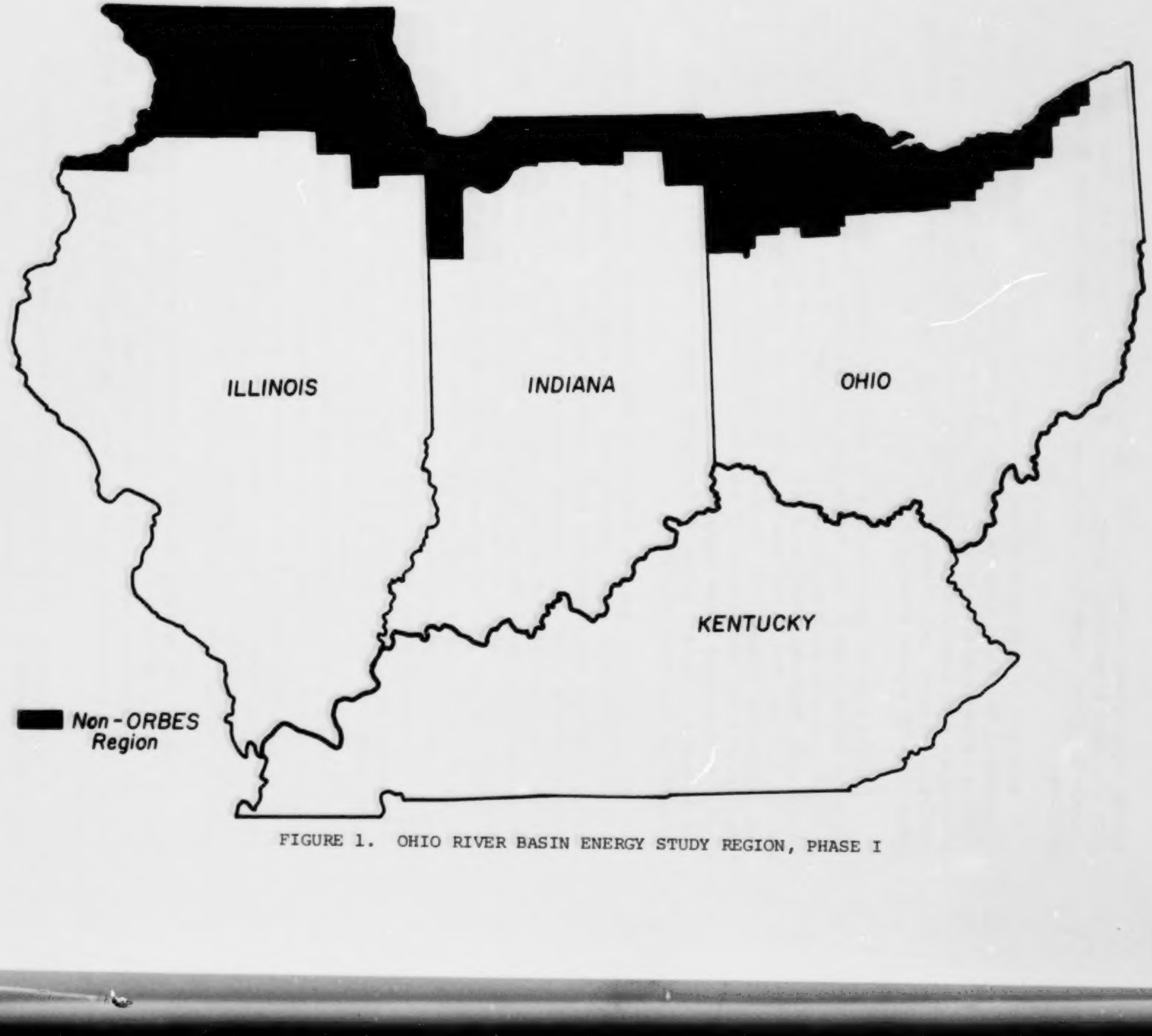
ILLINOIS
INDIANA
OHIO
KENTUCKY
Non-ORBES Region

FIGURE 1. OHIO RIVER BASIN ENERGY STUDY REGION, PHASE I

energy development impacts in the region cited. The overall project was entitled the Ohio River Basin Energy Study (ORBES). This report, *ORBES Phase I: Interim Findings*, summarizes major conclusions of these various first-year studies.

When grants were made to the six universities, EPA announced that they represented the first step in a proposed three-year study of possible energy impacts in the region. In Phase II, expected to last two years, the study boundaries have been extended to include most of West Virginia and southwestern Pennsylvania. See Figure 1 for the boundaries of ORBES Phase I, covering about 152,000 square miles.

Critical to an understanding of both this summary report and the broader study of ORBES Phase II are the social and political dynamics that initially focused attention on a particular 100-mile reach of the river, stretching from Louisville, Kentucky, northward and eastward to and beyond Cincinnati, Ohio. By the fall of 1974, a few months after embargo termination, area citizens began expressing concern over public utility proposals to locate coal-fired power plants on this stretch of the river bordering Indiana, Kentucky, and Ohio. Announcement a few months later by an Indiana public utility that it was planning a nuclear plant on the river between Louisville and Cincinnati intensified citizens' concerns.

To the utility planners themselves and to related industries (for example, coal interests) these plans seemed consistent with emerging national energy policies and compatible with economic and environmental constraints. These interests pointed to several conditions, among them the relatively low natural gas and petroleum prices, coupled with the Clean Air Act of 1970 and the accompanying environmental movement, that had forced utilities to shift in many cases from coal to oil and natural gas in operating their boilers. However, the embargo and fuel price structures were impelling the nation to reconsider the desirability of coal as a basic utility fuel. If coal were to be heavily used once again, existing federal and state regulations to clean up dirty air regions still would inhibit its use in plants in or near urban centers served by the utilities. Both coal-fired and nuclear-fueled plants require large amounts of land, and the 100-mile Ohio River reach described above contains long rural stretches remote from major population centers. River sites for the plants would be advantageous in that large amounts of water would be required for both cooling and processing. In addition, river transportation of both coal and plant equipment, in some cases in combination with existing rail lines, could be economical for utilities and related industries. Finally, the coalfields of Kentucky, Ohio, Indiana, Illinois, and West Virginia are within easy reach of this portion of the river.

Citizens who opposed the utility proposals, on the other hand, pointed out that the proposed plants need not necessarily be sited near major bodies of water. Among the other points they made was that much of the power expected to be produced by the plants would be transmitted far from the immediate area.

A brief history of the origins of the study against this backdrop is given in Appendix E.

In an effort to identify the implications of locating future energy conversion facilities in the "lower" basin, in 1975 the Senate Appropriations Committee directed EPA to perform a specific study:

> The Committee is aware of plans in various stages of development which could lead to a concentration of power plants along the Ohio River in Ohio, Kentucky, Indiana, and Illinois. Although the environmental impact of such a concentration could be critical, the decision-making authority regarding construction of these facilities is dispersed throughout the Federal government and several state governments.
>
> The Committee directs the Environmental Protection Agency to conduct. . . an assessment of the potential environmental, social, and economic impacts of the proposed concentration of power plants in the lower Ohio River Basin. This study should be comprehensive in scope, investigating the impacts from air, water, and solid residues on the natural environment and residents of the region. The study should also take into account the availability of coal and other energy sources in this region (1).

PROJECT STRUCTURE

To carry out the congressional mandate, EPA designed the first year of the Ohio River Basin Energy Study in the framework of four research tasks. Boundary determination and development of comprehensive scenarios for energy development in the four-state ORBES region were the responsibility of the Task 1 team. These scenarios were analyzed by three preliminary assessment teams (Task 2), composed of researchers from (1) Indiana University, The Ohio State University, and Purdue University, (2) the University of Kentucky and the University of Louisville, and (3) the Chicago Circle and Urbana-Champaign campuses of the University of Illinois. Task 2 findings were integrated and summarized in the present report (Task 3). This report also draws upon findings from ten special studies in areas requiring more detailed investigation than possible under Task 2 (Task 4).

PHASE I BOUNDARIES

An initial challenge facing Phase I researchers was determination of the precise boundaries of the "lower" Ohio River Basin consistent with the congressional mandate. As already noted, energy conversion developments in the four states of Illinois, Indiana, Kentucky, and Ohio were mentioned in the directive from Congress, but no specific boundaries were included.

In cooperation with EPA officials, the Task 1 group interpreted the mandate as requesting an assessment tied to the Eastern Interior Coal Province, approximately located in western and southern Illinois, southern Indiana, and western Kentucky. The relationship of this region to the concentrated pattern of proposed power plant construction along some stretches of the lower Ohio was viewed by EPA and the researchers as the principal focus of the initial year of ORBES. Major factors behind the overall boundary determination decision were:

--Congressional intent. Congress intended the study to focus on the lower portions of the Ohio River Basin and specifically mentioned the states of Illinois, Indiana, Kentucky, and Ohio.

--EPA counsel. EPA informed ORBES researchers that the entire state of West Virginia and a large portion of Pennsylvania were to be included in a separate regional energy development study soon to be funded by the agency. Since that study would focus on the Appalachian region (particularly Appalachian coal resources), it was decided that ORBES Phase I exclude these areas.

--Relevance of Illinois coal production. Following the congressional directive, the study format was designed to "take into account the availability of coal and other energy sources in the region." Therefore, the boundaries were extended beyond the Ohio River Basin to include most of the Eastern Interior Coal Province.

Thus, as already noted, the ORBES study region was defined to include about 152,000 square miles, some of which is coal-laden land outside the drainage basin. Also, for the reasons given, certain critical areas technically in the basin--notably most of the Tennessee River sub-basin--were excluded.

SCENARIO DEVELOPMENT

Technology assessments are conducted to delineate selected impacts associated with future events. In the case of the Ohio River Basin Energy Study, the impacts of interest are the possible environmental, economic, and social changes that might result from future levels of energy consumption and energy conversion facility development in the study region between the base year, 1975, and the year 2000. Such an assessment requires the projection of future energy demand, supply, and associated conversion facilities in the region. Because a single set of estimates like these may be quite different from the actual future, several plausible alternative levels of energy demand and supply must be studied. In general, these alternative levels, referred to as scenarios, are distinguished by possible future policies and the degree of implementation of these policies.

One way in which regional-level scenarios can be constructed is by taking already-developed national scenarios and adapting them to the particular region under study. In ORBES Phase I, two existing national scenarios were scaled down to the regional level. As described below, further adjustments were made to the two basic scenarios so that the gross national products (GNPs) projected under them were comparable. The scenarios also were adjusted to investigate the implications of alternative "mixes" of types of energy conversion facilities in the region.

One of the two basic scenarios employed depicts a relatively high rate of energy growth; the other, a relatively low rate. The high-energy growth option was based on 1975 U.S. Bureau of Mines forecasts (2), which take an essentially "business as usual" approach, with present trends projected into the future. The low-energy-growth option was drawn from the Technical Fix scenario in the Ford Foundation study entitled *A Time to Choose: America's*

Energy Future (3).[1] The major difference between these two basic options lies in the energy sector of the economy. The Technical Fix scenario assumes the widespread use of energy conservation measures and thus a decreased growth rate in energy conversion facilities, but it also assumes an increased growth rate in certain industrial sectors (such as service industries and household appliances).

To allow comparison between the BOM and FTF scenarios in the ORBES analysis, the methodology and logic of the much more complete Ford Foundation report were applied to the initial conditions stated in the Bureau of Mines report. The result was GNPs projected for the year 2000 that were comparable between the two basic scenarios. In the ORBES adaptation of the BOM and FTF scenarios, the gross national products projected for 2000 differ only to the extent that differences in the demand for energy between the two basic scenarios lead to differences in the mixture of goods and services necessary to supply this demand. It is of interest that thc unadjusted GNP used in the national FTF scenario was approximately 10 percent greater than that projected in the national BOM scenario. For both scenarios in the ORBES analysis, only parameters specified for the year 2000 were incorporated; by design, projections for intermediate years will not be in agreement with those of either national study if they are scaled down to the ORBES region (4).

The two basic scenarios were each broken down for purposes of ORBES into two mixes of types of energy conversion facilities. Thus actually four distinct scenarios were analyzed: two from the high-energy-growth Bureau of Mines forecasts and two from the low-energy-growth Ford Technical Fix projections. Because the major difference between the two basic scenarios is in electrical generation and supporting industries, electrical energy conversion facilities were emphasized during the first year of ORBES.

Both high-energy-growth scenarios, adapted from the BOM projections, assume a 5.4 percent annual electrical energy growth rate between 1975 and 2000. Although the BOM projections for the year 2000 were preserved, as noted above, project researchers made some modifications in the rate at which power plants would be brought on-line in the ORBES region to supply this energy. The schedule for plant additions between 1975 and 1985 was assumed to be identical to the schedule announced by the utilities for the study region during this time span; this schedule is the same for both high-energy-growth scenarios.

From 1986 through 2000, plant additions and replacements would be sufficient to meet the region's needs as projected by BOM, but with different fuel mixes for the two high-energy-growth scenarios. In the first BOM scenario, the mix was set at 80 percent coal and 20 percent nuclear for those facilities assumed to be built in the region between 1986 and 2000--a total of 131 coal-fired units and 28 nuclear-fueled units. In the second BOM scenario, the fuel mix was 50 percent coal and 50 percent nuclear during this period; 80 coal-fired units and 79 nuclear-fueled units were projected. All new facilities were assumed to consist of 1000 megawatts electric (MWe) units.

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[1] It should be noted that the Historical Growth scenario, also examined in the Ford Foundation study, differs in important respects from the Bureau of Mines scenario adapted for ORBES. For example, while the Bureau of Mines scenario assumes major reductions in the use of natural gas, the Historical Growth scenario assumes continued reliance on this energy source through the year 2000.

The two low-energy-growth scenarios, based on FTF projections, call for a 3.3 percent and 2.43 percent annual growth in electrical energy for the periods 1975-1985 and 1986-2000, respectively. A comparison of the capacity of the utility-announced additions for the year 1985 and the FTF projections for the year 2000 reveals that 1985 announced capacities constitute 93 percent of the FTF projections for 2000. Thus under the low-energy-growth scenarios only 6200 additional megawatts electric of installed capacity would be required to meet demand in 2000 and to replace existing plants that are scheduled to be retired.

In the ORBES scenarios, the plant schedule announced by the utilities was altered to be compatible with the FTF projections. One FTF scenario assumes that all additions or replacements necessary to meet projections for the year 2000 will be coal fired; 27 units of 600 MWe each were projected for the study region. The second FTF scenario assumes that these additions or replacements will be nuclear fueled--a total of 16 units of 1000 MWe each.[2] See Appendix F for a list of assumptions behind the ORBES scenarios, constraints on siting the hypothetical energy conversion facilities, and maps showing siting configurations.

The differences among scenarios in the number of electrical generating facilities projected are quite significant, ranging from a total of 159 units in the BOM 80 percent coal/20 percent nuclear scenario to 16 units in the FTF 100 percent nuclear scenario. Local differences between the two high-energy-growth scenarios also could be significant in considering relative impacts of coal-fired and nuclear-fueled installations, but differences between the two low-energy-growth scenarios would be slight. By analyzing the implications of the very different, though plausible, futures portrayed by the BOM and FTF scenarios, it is possible to contrast the variety of consequences and impacts that a range of futures might have upon the ORBES region.

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[2] Subsequently the ORBES analysis found that in certain areas few differences emerged by contrasting impacts either between the two FTF scenarios or between the two BOM scenarios. In this report, comparisons of the two basic energy-growth options are really comparisons of the BOM 80 percent coal/20 percent nuclear scenario and the FTF 100 percent coal scenario (4). In such cases, the high-energy-growth option is sometimes referred to as the high-energy-growth scenarios or the BOM scenarios, even though only one BOM scenario was actually analyzed. Similarly, the low-energy-growth option is sometimes referred to as the low-energy-growth scenarios or the FTF scenarios.

CHAPTER 3

IMPACTS ON NATURAL RESOURCES

The Ohio River Basin is rich in natural resources and is part of the great midwestern land mass making up the heartland of America. Feeding upon an abundance of coal and water, the upper basin is dominated by heavy and medium industry, especially steel and chemicals. The lower basin contains some of the richest and most productive agricultural land in the world. One-third of the nation's corn and soybeans is grown in the ORBES region; about 30 percent of the nation's deposits of bituminous coal underlies some of that same land. Binding this natural abundance together are the Ohio River and its tributaries--a source of water for the many competing regional needs for this resource as well as a national transportation route linking the eastern United States to the Mississippi and Missouri rivers and to the rest of the world.

The following discussion, dealing with land, water, and mineral use in the ORBES region, attempts to assess the direct impacts on these resources to the year 2000 under the differing assumptions of the scenarios. (Land and water quality are considered in Chapter 4.) Policy issues raised by these potential impacts are listed at the end of the chapter.

LAND USE

In any energy-growth scenario, the basic problem in land use is the conflict between commitments of land to energy and commitments to other present or potential uses. In the ORBES region, this conflict is dramatic, since it tends to be between food and energy. Recently food shortages have become recognized as a growing global problem, as has the finiteness of world energy resources. The "rediscovery" of coal as a prime energy source also is recent. Little precedent exists for resolving effectively, with deference to future generations, these fundamental and conflicting problems. Although strict land reclamation laws have begun to emerge in the ORBES-region states and at the federal level, the amount of time and capital necessary for full reclamation is not clear.[1] Indeed, reclamation technology is neither well developed nor well understood.

Coal extraction, conversion, and transmission are only one competitor for land use. Agricultural land is taken out of production for a wide variety of other reasons, including urban growth, suburbanization, industrialization, and commercialization, as well as meeting public demand for open space and recreational areas. The increase in these land-use functions would be greater and more permanent than coal-related activities. The aggregate of these pressures, plus suspected and known environmental impacts upon land productivity, is cause for concern.

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[1] See Reference 5 for citations to land reclamation laws in Illinois, Indiana, Kentucky, and Ohio.

The methods used to obtain quantitative estimates of the land required for each energy-related use vary considerably. However, when both quantitative and qualitative aspects are evaluated, the impacts, in descending order of severity, can be ranked as extraction, conversion, electrical transmission, waste disposal, processing, and transportation (excluding electrical transmission lines).

Extraction

Coal underlies approximately half of the ORBES region. This coal is of two major types, that located in the Eastern Interior Coal Province and that in the Appalachian portion of the region. The land area affected by coal mining in the region under the scenarios will differ by many factors. The estimates given below are for the region as a whole, not by production area.

Estimates of the land area affected by surface extraction of coal can vary widely depending on the assumptions used in making calculations. Land involved in surface mining is heavily impacted, but in most cases it can be returned to some productive use. Under the scenarios, the amount of ORBES-region land affected between 1976 and 2000 is estimated to range from 258 square miles for the Bureau of Mines 80 percent coal/20 percent nuclear scenario to 140 square miles for the Ford Technical Fix 100 percent nuclear scenario (6) (see Table 1).

Because of the greater amount of electrical power generated under them, the high-energy-growth (Bureau of Mines) scenarios would have more severe land-use impacts than the low-energy-growth (Ford Technical Fix) scenarios in the 152,000 square miles making up the ORBES region. Between 1976 and 2000 under the high-coal BOM scenario, about 2700 square miles would have been devoted permanently or temporarily to energy activities. Because of the lower extraction efficiency for deep mines, much greater land areas would be subjected to underground than to surface mining, ranging from about 1400 square miles under the BOM 80/20 scenario to about 800 square miles under the FTF 100 percent nuclear scenario.

Subsidence (settling of the surface due to the collapse of abandoned mines) is a potential major problem. Historic experience indicates that only a small portion (perhaps 5 to 10 percent) of the area potentially subject to subsidence will actually subside within 100 years after mining activity. Thus, most of the land surface potentially affected by underground mining under the scenarios would show little disturbance in the time span covered. In most instances, the surface damage from subsidence (for example, damage to agricultural tile drainage) can be repaired readily, and the land returned to its previous use, at some expense to the landowner. Assuming enforcement of current reclamation regulations, only a very small portion of the land affected by coal extraction would be unavailable for productive use at any given time.

TABLE 1. SELECTED ESTIMATES OF LAND AREAS POTENTIALLY SUBJECT TO IMPACTS, ORBES REGION, BY SCENARIO, 1976-2000
(in square miles)

Function	BOM 80/20	BOM 50/50	FTF 100% coal	FTF 100% nuclear
Coal extraction and processing	1668	1466	1034	968
surface	258	188	145	140
deep	1410*	1278*	889*	828*
Conversion	339	368	70	80
coal	261	178	55	32
nuclear	78	190	15	48
Electrical transmission	717	717	177	177
Total	2724	2551	1281	1225

*Includes all surface area involved in underground and aboveground operation.

NOTE: Assumptions behind the figures in this table are found in Reference 6.

The use of reclaimed land might be the same as that before the land was mined. However, it would take many years for farmland, for example, to be returned to a reasonable level of productivity, which probably would not approach previous levels. The amount of time and money required for reclamation is a function both of the quality to be achieved and of the particular land characteristics. There can be a vast difference, of course, between the simple reclaiming of land (which may involve only leveling) and restoration (a return to former use and productivity).

Conversion

Substantial amounts of land also would be affected by energy conversion facilities. Such land is acquired by utility companies either by negotiations with individual landowners or by the use of eminent domain. In addition to direct electrical generation, the conversion function includes land required for cooling, fuel storage, and on-site waste disposal. Almost all the land area on a fossil-fueled power plant site is utilized by the various steps in the operation of the plant, while only about 25 percent of the land on a nuclear-fueled power plant site is so used. The remaining 75 percent constitutes a safety zone to protect the public from exposure to radiation.

Estimates of the land area required through the year 2000 for conversion facilities under the BOM scenarios are about 340 square miles for the BOM 80/20 and about 370 square miles for the BOM 50/50, respectively. Under the FTF scenarios, estimates are 70 square miles (FTF 100 percent coal) and 80 square miles (FTF 100 percent nuclear).

Electrical Transmission

New transmission lines and storage would require about half the area (717 square miles) of that required for mining under either BOM scenario. About one-fifth the land area (177 square miles) of that required by mining would be needed for transmission under either FTF scenario. Where these lines cross prime agricultural land, however, approximately 80 to 95 percent of the land initially affected can be returned to productive use within a year. Approximately 5 to 20 percent of the initially impacted land would be dedicated for the foreseeable future to substations, access roads, and support towers. In forested areas, permanent land-use change would result from the presence of all transmission rights-of-way.

Waste Disposal

Coal-conversion facilities, particularly plants using lime or limestone scrubbers, generate large volumes of waste that generally are stored on site. This land requirement (about 2400 acre-feet to store the fly-ash and scrubber sludge produced by a 1000 MWe plant over a 30-year life (7)) was included in calculating land devoted to the conversion function under the four scenarios. Coal mining and processing also generate large amounts of waste that are disposed of on site or, in mountainous terrain, on adjacent slopes. These impacts are reversible to the extent that the land can be reclaimed and returned to its previous use or diverted to some other use.

The nuclear fuel cycle produces hazardous wastes that probably would be concentrated on site and at regional waste-disposal sites. The ORBES region contains two low-level waste-disposal sites and is a possible location for a high-level waste repository. Although estimates vary as to the amount of land required for nuclear waste disposal, such disposal requires more land than the amount of waste would seem to indicate. This can be traced to the need for buffer zones and the fact that a suitable universal waste-disposal method has not been developed. Land devoted to nuclear waste disposal would be lost irreversibly to other productive uses.

Processing

A high proportion of coal is cleaned near the mine, or at least in the state where it is mined. The refuse accumulating from the cleaning stations creates some of the most toxic areas produced by the coal industry. Under the BOM high-coal scenario about twice as much land would be affected as under either FTF scenario. Under any scenario, however, land requirements for processing would be only about one-seventieth of those for mining.

Transportation

Additional land required for transportation support of energy-related functions under the scenarios would be negligible. Existing transportation rights-of-way could accommodate road widening, or double tracking in the case of railroads, without significantly disturbing additional land. Coal slurry pipelines, natural gas and oil pipelines, and barge terminals for the transshipment of coal would require small amounts of additional land.

Utilization

The scenarios would require extensive amounts of land to accommodate the energy-consuming activities such as industry that would be associated with economic growth. The land required to support such activities probably would be as great or greater than that dedicated to energy production.

An approximation of the amount of land potentially involved can be obtained by apportioning the national historic urban-conversion rate to the ORBES region by population ratio and linearly extrapolating to the year 2000. The amount of land converted to urban uses in the region between 1976 and 2000 would be about 2000 square miles. This is comparable to the total of approximately 2800 square miles that would be utilized under the BOM high-coal scenario for energy-related activities (6). This figure, however, *does not* take into account either regional differences in population and economic growth or changes and differences in standard of living.

Land-Use Conflicts

Much of the ORBES region lies within zones of unique climate and soils particularly suitable to the production of corn, soybeans, and tobacco. The major impact of land-use changes probably would be on land currently used for these and other agricultural purposes, including privately owned forest land. Comparison of the location of coal reserves, crop land, and forest clearly demonstrates the potential conflict between coal development and agriculture in the Illinois, Indiana, Ohio, and western Kentucky portion of the ORBES region and between coal development and forestry in the Appalachian portion.

In addition to this possible food-energy conflict, another potentially serious conflict is energy development and its concomitant economic activity, on the one hand, and preservation of historical and archaeological sites, on the other. This conflict has already been illustrated in the ORBES region, where remnants of both American Indian culture and of nineteenth-century industrial development are found. Under the National Historic Preservation Act, the plant-siting process must take these factors into account. It should be recognized, however, that in most cases under this law, historic and archaeological sites only must be studied, not necessarily preserved.

An additional potentially serious land-use conflict is that between energy development and the many scenic, natural, and recreational areas in the ORBES region, especially along the Ohio River and its tributaries. For example, the river bottomlands of western Kentucky and southern Illinois are habitats for plant and animal species today found nowhere else in the region (8).

HYDROLOGY AND WATER USE

There are two major hydrological and water use impacts of energy production: changes in the distribution and rate of flow due to mining and reductions of flow due to consumption.

Hydrology

Surface mining has a major impact on local water flow, especially during storms. Water diversion structures often intercept overland flow and speed its deliverance to surface water courses. Detention ponds for sediment control have the opposite effect: overland flows and small-stream flows are collected and retained, while sediment falls from suspension. Underground drains for ground-water interception do not modify the hydrological system as much as do diversion structures and sediment ponds.

Deep mining and associated reclamation efforts to prevent acid mine drainage may affect local surface flows to a varying extent, depending on the local ground-surface-water relationships. Water-removal operations during mining frequently increase the base flows of streams; large volumes discharged into small streams may change their character and storm-carrying capacity.

Water Use

A major conclusion of the ORBES research on water use, described in detail below, is that under the high-energy-growth scenarios, consumptive losses of water would be extremely high for many Ohio River tributaries and moderately high for the Ohio itself. Consumptive losses are of primary importance because they are not returned to streams and thus are lost for other off-stream uses or for maintaining stream flows and water quality. During low-flow conditions, some stream flows would be decreased significantly under both high-energy-growth scenarios. Under the low-energy-growth scenarios this impact would be much less severe. Extensive development of irrigation, however, would compound impacts under both energy-growth options.

Water Use Estimates. Based on the projected growth in energy facilities between 1970 and 1985 (essentially the same for all four ORBES scenarios), water consumption estimates would increase sharply, from 1000 cubic feet per second (cfs) in 1970 to 3000 cfs in 1985 for the region as a whole. The major reason for this tripling of water consumption is the assumption that evaporative ("wet") cooling towers would be employed by all plants--even existing ones, which would be retrofitted or ultimately replaced. In 1970, municipalities and industries accounted for approximately 90 percent of total consumption, but in 1985, they are estimated to account for only 37 percent. The remaining 63 percent would be for power-related consumption. This does not take the role of irrigation into consideration. Total water withdrawal in the region is estimated to decrease from 60,000 cfs in 1970 to 14,000 cfs in 1985, due to the assumed elimination of once-through methods of cooling by power plants (9). See Appendix G for tabular summaries of these and other data on water use.

In the year 2000 under the BOM scenarios, power-related water consumption could be as much as 75 percent of total projected consumption. Either high-energy-growth scenario would require more than 6000 cfs; either low-energy-growth scenario, more than 3500 cfs. The difference between the BOM 80/20 and the BOM 50/50 scenarios is relatively small: the total water consumption estimate for the latter is approximately 7 percent greater because nuclear plants require more water for cooling. The estimate for the FTF 100 percent nuclear scenario is only 3 percent greater than for the FTF 100 percent coal scenario (9).

Under the scenario calling for the most water use, the BOM 50/50, incremental water consumption would be about 14 percent of the 7-day 10-year low flow of the Ohio River; it is significant in regard to both water quality and navigation of the waterways.[2] At the other extreme, under the FTF 100 percent coal scenario, incremental consumption would be about 6 percent of the Ohio's 7-day 10-year low flow.

When the total consumption estimates for the BOM 50/50 scenario are compared to the estimated low-flow runoff from within the ORBES region, however, the figures become much larger. (Low-flow runoff represents the water flow added to river basins by rainfall on the basin by the watershed of the region, but it does not include the flow brought into the region by streams.) Under the BOM 50/50, the overall comparison of consumption to runoff for the ORBES region would be 87 percent. Of the four ORBES-region states, the maximum figure, 115 percent, would occur in Ohio. These figures highlight the extent to which flow in the Ohio River and its tributaries depends on inflows from outside ORBES-region boundaries. Estimates for Illinois, for example, indicate that incremental consumption would be only 3 percent of the total flow but 87 percent of the runoff from within the state. This striking difference would result from the very large flow in the Mississippi River. Future development in adjacent regions, however, could lead to competition for water resources. In particular, there is a large potential for irrigation in the Missouri Basin, which drains into the Mississippi River. Similar conditions hold for Indiana, Kentucky, and Ohio. If this competition becomes severe, navigational problems could arise under low-flow conditions, especially on the tributaries. (Effects in such areas as fishery resources and recreation also might be felt, but these effects could not be analyzed during ORBES Phase I.) The dependence on inflow would be much less under the FTF 100 percent coal scenario; total consumption estimates would be 40 percent of runoff, with correspondingly lower estimates for the individual states (9).

Potential Role of Irrigation. At present, there is little irrigation in the ORBES region, and thus it was not considered in the discussion of water consumption above. Many questions surround its development in the region. Recently, however, the possibility of supplemental irrigation during drought periods has been receiving increasing attention.

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[2] Incremental consumption is the difference between consumptive water losses and available surface-water supplies during low-flow conditions.

Water consumption estimates for irrigation in the year 2000 were calculated for low, moderate, and high levels of irrigation in the region. The low estimate is based on data for irrigated acreage in recent periods and assumes no additional development; 500 cfs would be required for 93,000 irrigated acres. The moderate and high estimates correspond to significant expansions of irrigated acreage: 2100 cfs would be required for 390,000 irrigated acres; 3800 cfs, for 710,000 irrigated acres (9).

These consumptions estimates indicate that irrigation development could entail significant levels of water consumption relative to the total consumption estimates for municipal, industrial, and power-related uses under the two extreme ORBES scenarios. Under severe drought conditions, irrigation demands could become equal to the water requirements of BOM and greater than the requirements of FTF. These irrigation demands would be met from some combination of ground- and surface-water sources. Depending on the extent to which surface water is used, the impact (in conjunction with that of the other uses) on the 7-day 10-year low flow could be significant.

Effects of Water Consumption on the Major River Basins. A convenient way to quantify the impact of water consumption on a river is to use the consumption ratio. This ratio is defined as the ratio of cumulative water consumption to the 7-day 10-year low flow.[3] The impact of consumption is defined arbitrarily as light, moderate, or heavy if the average consumption ratio is 5 percent or less, between 5 and 25 percent, or over 25 percent, respectively. Due to incoming tributaries and changing use, the ratio changes along different reaches of a river. The ratio also can be useful in determining the effect on depth of navigational channels.

Consumption ratios for different reaches of ORBES-region rivers were calculated for each scenario. Existing plants were not considered in this analysis, but rather only those plants projected under the scenarios. Under the high-consumption BOM scenario, heavy impacts would result for the Scioto, Great Miami, Kentucky, Salt, Saline, Kaskaskia, Big Muddy, and Illinois rivers. For the Ohio River itself, a moderate impact would result--an average consumption ratio of 10 percent for all reaches. In contrast, under the extreme FTF scenario the impact on the Ohio River would be light--a consumption ratio of only 2 percent. Most of the other impacts calculated under this scenario also would be light or moderate (9).

MINERAL RESOURCES

Under both the high- and low-energy-growth options, the use of coal, lime and limestone, and uranium to supply electrical generating plants would have major effects on mineral resources. The scenarios assume that flue-gas desulfurization systems are installed and work efficiently; this could also mean major impacts on the lime industry and moderate impacts on the limestone industry. The greatest effects would occur under the BOM scenarios, since they call for the greatest increase in installed electrical capacity. At the local level, shortages of construction materials would be expected under all four scenarios. These potential impacts are discussed in the following subsections.

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[3] In 1930, the flow was well below the 7-day 10-year low flows of recent history. For example, for 143 consecutive days during that year near Louisville, Kentucky, at the McAlpine Dam, the flow was well below the usual flow of about 15,000 cfs.

Coal

The ORBES region, which includes the large Eastern Interior Coal Province, has abundant coal reserves, estimated at about 30 percent of total national reserves. This coal represents a major energy source, but the majority of it has a high sulfur content. The bulk of the low-sulfur coal in the region is found in eastern Kentucky in the central Appalachian Coal Province.

In 1975, the electric utility industry consumed about two-thirds of total U.S. coal production; almost half of this total was supplied by the ORBES region. Of the total national production, about 14 percent was used for coke, with most of the remainder exported or used by industry for process steam, space heating, and other industrial uses.

Environmental restrictions as well as cost and technological factors dictate the coal mix used by a utility. Thus although regional coal produced in 1975 would have been sufficient to supply all the electric utilities within the region, its high sulfur content posed a problem. Rather than burning this coal with the use of flue-gas desulfurization systems, most utilities chose to import low-sulfur coal when required to meet sulfur dioxide emission standards.

Assuming an overall mining extraction efficiency of 70 percent and a mix of eastern and western coal used by ORBES-region electric utilities, coal consumption by these utilities under the BOM 80/20 scenario would mean a 1.8 percent reduction in regional coal reserves between 1975 and 2000. If, on the other hand, it is assumed that the four ORBES states use only coal from within the regional boundaries throughout the study period, under this high-coal scenario the region would consume 2.4 percent of its reserves during this time. This scenario would require about four times as much coal in the year 2000 as in 1975. Coal production would have to be increased significantly to meet this demand, but if the utilities did not use flue-gas desulfurization systems to meet air quality emission standards, then the trend toward importing increasing amounts would accelerate greatly.[4]

Lime and Limestone

The ORBES scenarios assume that after 1985 flue-gas scrubbers with lime or limestone as the scrubbing medium will be used to remove sulfur in all plants burning high-sulfur coal. Thus the demand for these resources would increase. Limestone is generally a plentiful material in the ORBES region;

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[4] Recent amendments to the Clean Air Act will require future plants to use flue-gas desulfurization systems.

most of it is obtained from open-pit mining operations. The quantity of lime or limestone required for flue-gas desulfurization for a particular plant would depend on the sulfur content of the coal burned and, more important, on EPA emission standards.

The amount of limestone required to meet the potential new demand could reach 50 million tons per year by 2000 for the high-coal BOM scenario. This would require a moderate increase in the amount of limestone produced in the region. On the other hand, if lime is the preferred reactant for use in wet scrubbers, impacts on the lime industry would be very significant. To meet this new demand, the national (and ORBES-regional) supply of lime would have to be increased greatly from the approximately 22 million tons produced nationwide in 1974. In the year 2000, the BOM 80/20 scenario would require more than twice this amount of lime.

Uranium

Most U.S. uranium comes from sandstone and mudstone deposits located outside the ORBES region. Some low-grade uranium deposits are located in the region, but because they are not competitive economically, at present they are not mined.

To determine uranium ore depletion, it was assumed that if an ore deposit required underground mining, only 50 percent or less of the ore in the deposit would be recoverable. With surface mining, 80 percent or more of the ore was assumed to be recoverable.

Assuming that one-third of the fuel used in a nuclear plant is replaced each year and that no recycling of uranium and plutonium occurs, the yearly mining requirement for each 1000 MWe power plant is about 110,000 tons of ore. Each reactor requires an initial fuel load of about 430 tons of U_3O_8, commonly called yellowcake, which is converted to enriched fuel. Total cumulative yellowcake requirements for the four scenarios, including initial fuel loads and requirements through the year 2000, range from 23,000 tons for the FTF 100 percent coal scenario to 165,000 tons for the BOM 50/50 scenario.

It is clear that the BOM 50/50 scenario would require a decided increase in exploratory and development drilling by the uranium industry. The costs of such drilling and of the subsequent extraction of lower grade ore than used at present would drive up prices. The reserve base from which development would take place would be expanded greatly. In terms of reserves, the BOM 50/50 would require that approximately 40 percent of known U.S. uranium reserves available for sale at $15 per pound be committed to ORBES-region utilities through the year 2000. As shown in Table 2, substantial uranium reserves would be required to fuel these plants for their expected useful economic lives beyond the year 2000. (More exploration would increase the known reserve base greatly.) The BOM 80/20 scenario would require less uranium ore, approximately 20 percent of known U.S. reserves, but much more than either FTF scenario (about 9 percent for the 100 percent nuclear scenario and about 6 percent for the 100 percent coal scenario). In contrast, of the known U.S. reserves available for sale at $50 per pound, the BOM 50/50 scenario would require approximately 20 percent; the BOM 80/20, approximately 10 percent; the

FTF 100 percent nuclear, approximately 4 percent; and the FTF 100 percent coal, approximately 3 percent (see Tables 2 and 3).

TABLE 2. URANIUM FUEL NEEDS, PLANT LIVES OF 30 YEARS
(in tons of U_3O_8)

Scenario	First load and through 2000	Beyond 2000
BOM 50/50	165,000	623,000
BOM 80/20	82,000	232,000
FTF 100% nuclear	35,000	154,000
FTF 100% coal	23,000	45,000

SOURCE: Reference 6.

TABLE 3. UNITED STATES URANIUM RESOURCES, JANUARY 1, 1977
(in tons of U_3O_8)

Cost category per pound of U_3O_8	Reserves	Potential resources* Probable	Possible	Speculative
$10	250,000	275,000	115,000	100,000
$10-$15 increment	160,000	310,000	375,000	90,000
$15	410,000	585,000	490,000	190,000
$15-$30 increment	270,000	505,000	630,000	290,000
$30	680,000	1,090,000	1,120,000	480,000
$30-$50 increment	160,000	280,000	300,000	60,000
$50	840,000	1,370,000	1,420,000	540,000

*The reliability of potential resource estimates decreases from the probable to the speculative categories.

SOURCE: Reference 10.

If they were to become economically and technologically feasible, several undemonstrated technologies could alleviate the problem posed by the BOM requirements. Reprocessing spent fuel would ease the demand for uranium ore supplies, since it would provide reusable uranium and plutonium. Using plutonium in a self-generated mixed-oxide form could extend the available energy a few more years. However, use of plutonium in breeder reactors (such as the liquid-metal fast-breeder reactor) could extend uranium as a resource for several centuries, if such reactors were to become commercially available. Another form of fission fuel, thorium, also is available. Used in the high-temperature gas-cooled breeder reactor or the light-water breeder reactor, thorium can breed U_{233} (a uranium isotope); this could approximately double the potential energy available from uranium. However, the commercial viability of all these technologies is open to serious question; in any case, none could be in widespread use before the year 2000. Further, unresolved questions exist regarding effects of these technologies on the environment and on human health.

Construction Materials

Construction of the projected power plants might lead to short-term shortages of materials (crushed rock, gravel, cement, lumber, and road material) and of large dirt-removing equipment in the local construction site area, especially during the three- to four-year period when plant construction is at its peak. Because nuclear units are designed to withstand greater seismic loads as well as to contain the release of radioactive materials from small operating accidents, they use more material than do coal units. Accurate estimates of construction material requirements are difficult to make, however, because each is site specific.

ILLUSTRATIVE POLICY ISSUES

Land Use

--What level or levels of government should be responsible for land-use controls that promote energy development in or restrict it to selected areas?

--Should government at various levels become involved in encouraging the the development of industrial and urban use of strip-mined land, thereby concentrating development in areas already impacted and avoiding both the disturbance of additional land and the high cost of returning strip-mined land to productive agricultural use?

--In view of the nation's energy dilemma, what relative emphases should government place on the use of land for energy development, on the one hand, and for such other uses as agriculture, recreation, and open space, on the other?

--What should the roles of state and/or local governments be in reviewing and determining the final acceptability of sites for the long-term storage of radioactive wastes? What should be their roles in monitoring these sites? (also listed in Chapter 5)

--How can individual rights best be balanced against the use of eminent domain for energy-related facilities to promote the public good?

--Land values on the private market can be affected adversely by effects of energy-related facilities (for example, the downwind effects of power plant emissions). What institutional mechanisms, if any, should be developed to compensate owners of this land?

Hydrology and Water Use

--What policies should be developed to deal with the effects of upstream water use on water availability for power plants and other uses in the ORBES region?

--Are future water losses through the use of current power plant cooling technologies of sufficient concern in the ORBES region to justify government leadership in considering alternative cooling technologies?

--If consumptive withdrawals of ground water increase significantly, what changes in water allocation, if any, should be instituted to protect both holders of traditional riparian rights and users of ground water? For example, should riparian rights be replaced by a different water allocation mechanism, such as permitting?

--To what extent is the reuse of water a feasible solution to potential water shortages? If such reuse is feasible, how can it be encouraged through government initiative?

Mineral Resources

--Should the ORBES-region states cooperate in developing more environmentally benign technologies for the utilization of high-sulfur regional coal than exist at present?

--Should the federal government or the ORBES-region states encourage utilities and other coal consumers to utilize as much low-sulfur coal as possible from within the region or from neighboring states (as opposed to western coal) to fuel existing plants?

--What role, if any, should the ORBES-region states play in protecting the public interest with respect to uranium availability, reprocessing spent fuel, and the breeder reactor?

CHAPTER 4

IMPACTS ON DEVELOPED RESOURCES

There are well-developed institutional relationships within the ORBES region to support the industrial and agricultural economic base. Institutions for capital generation exist, diverse materials transportation systems are in place, and a labor force possessing a wide spectrum of skills is present. These characteristics of the region are the result of its industrialization as early as the 1850s. The region also contributes to and draws upon national markets that produce the manufacturing systems needed for large-scale energy extraction, conversion, and distribution.

The following sections describe the impacts that the ORBES scenarios would have on materials transportation systems, industrial production, capital for electric utilities, and labor needs. Policy issues suggested by these potential impacts appear at the end of the chapter.

TRANSPORTATION

Increased materials transportation needs under the various scenarios would occur primarily under the high-energy-growth Bureau of Mines scenarios, which would require greatly increased coal and limestone transport, particularly by barge and rail. The low-energy-growth Ford Technical Fix scenarios would mean only a modest increase in transportation needs.

There are many ways to improve the transportation systems' efficiency and/or reduce costs so that the most efficient modes are utilized (11). Improved technologies such as regional coal-loading facilities with unit trains and rapid loading and unloading facilities for hoppers and barges would achieve both of these objectives. Upgrading railroad tracks and roadbeds, eliminating bottlenecks and other delays, and increasing the capacity of the various systems all would lead to greater efficiency. Transportation efficiency also would be improved by allocating costs of the various modes fully to the user, for example, by tolls or taxes. Historically, some forms of transportation, such as railroads, come closer to paying their full share of costs than do others, such as barges and trucks.

Although one ORBES assumption is that after 1985 extensive use will be made of flue gas desulfurization systems (scrubbers), transportation needs associated with the resulting sludge and fly ash would be minimal under all of the scenarios. Under current practice, these materials are deposited on site, and large-scale transportation of fly ash and scrubber sludge would occur only if it became uneconomical (or physically or legally impossible) to continue this practice.

Because the bulk of uranium ore is first processed and reduced near the mine mouth (at present no uranium is mined in the ORBES region), increased numbers of nuclear reactors, even under the BOM 50 percent coal/50 percent nuclear scenario, would not strain the transportation systems severely.

The major issue in the transportation of nuclear material is security, with respect to both accidents and sabotage. The BOM 50/50 scenario, with 79 nuclear units by the year 2000, obviously would pose the greatest problems for safety and safeguards because of the large amount of fissionable material that would be transported. If many local communities decide to restrict nuclear shipments within their boundaries, trucks might come into greater use because they can be rerouted around cities. The transportation projections then might have to be changed.

At individual plants, the effects of automobile traffic congestion are not expected to be a major problem under any of the scenarios. However, concentrated growth in one part of the region could cause locally severe effects. In some localities, barges and trains could lead to increases in noise and particulate levels. These impacts would be greatest under the high-energy-growth option and probably would be negligible under the low-energy-growth option.

INDUSTRIAL PRODUCTION

National Production

Although the focus of ORBES is on regional impacts, certain national trends are likely to be experienced within the region. This is the case with the impacts on industrial outputs associated with the high- and low-energy-growth options. Under both options there would be significant national impacts, both positive and negative, on the total production of industries supplying goods either to energy-related activities or for energy conservation. Approximately the same level of gross national product is maintained in both the BOM and the FTF scenarios (see Chapter 2). Therefore, although there would be differences in the distribution of production among industrial sectors, the total production in dollar amounts would be virtually identical for both energy-growth options. The GNPs projected under both options for the year 2000 as adapted for ORBES would differ by less than 1 percent (4).

The industries with projected major differences in output between the two energy-growth options in the year 2000 appear in Table 4, which shows projected percentage changes in the dollar value of industrial outputs under each option. A positive difference shows greater dollar output for a given industrial sector under the low-energy-growth (FTF) scenarios relative to the high-energy-growth (BOM) scenarios; a negative difference, greater dollar output under the BOM scenarios relative to the FTF.

The greatest differential of the low-energy-growth option over the high-energy-growth option in the year 2000 would be in the natural gas utility sector, where the FTF scenarios would be expected to have 25 percent greater production than the BOM. The reason for this difference lies in several assumptions made in constructing the national Ford Technical Fix scenario:

TABLE 4. SCENARIO EFFECTS ON NATIONAL INDUSTRIAL OUTPUTS, 2000
(18 of 185 sectors)

Rank	Sector	$\left[\frac{\text{FTF} - \text{BOM}}{\frac{\text{FTF} + \text{BOM}}{2}}\right]\%^*$
1	natural gas	25
2	other stone and clay products	8
3	household appliances	7
4	service industry machinery	3
5	paving and asphalt	2
6	motors and generators	2
7	plumbing and heating equipment	1
8	millwork and wood products	1
176	pottery	-9
177	new construction	-9
178	mechanical measuring devices	-11
179	structural metal products	-12
180	nonferrous wire drawing	-13
181	pumps, blowers, compressers	-14
182	transformers and switchgear	-16
183	industrial patterns	-18
184	coal mining	-30
185	electric utilities	-62
	all industries	-2

SOURCE: Reference 4.

[*] A positive difference means greater dollar output under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater dollar output under the BOM scenarios relative to the FTF scenarios. Sectors are ranked in terms of the differential dollar output between the two basic options.

unfavorable domestic petroleum supply conditions and restrictions on petroleum imports (leading to sharp increases in petroleum product prices) and a relatively slow productivity advance in electrical generation (leading to higher electricity prices). These price increases also would mean higher prices for natural gas, but in the FTF scenario the natural gas sector maintains a stronger relative position than does either electricity or petroleum (3). The national Bureau of Mines scenario, on the other hand, assumes major reductions in the use of domestic natural gas--a 20 percent decline between 1974 and 2000--although reliance on synthetic and imported gas is assumed to increase, as is reliance on petroleum (2).

As shown in Table 4, the industrial sector with the largest relative differential of the high- over the low-energy-growth option in the year 2000 would be electric utilities (62 percent). The remaining nine industries showing negative differential outputs (and therefore greater output of the BOM relative to the FTF scenarios) are major suppliers to the electric utilities. Of the ten sectors, two--electric utilities and coal mining--plus natural gas, would be affected directly by the energy-demand assumptions of the two basic options, especially the higher unit prices for energy assumed under the FTF scenarios as the result of government intervention.

The greater relative outputs under the FTF scenarios of the remaining sectors (other stone and clay products, household appliances, service industry machinery, plumbing and heating equipment, and millwork and wood products) would be attributable to expenditures for energy conservation. (Other stone and clay products include materials for insulation such as asbestos; service industry machinery includes commercial and industrial air conditioning, warm air heating, and refrigeration equipment.) Similarly, production of motors and generators would increase as the result of increased activity in the household appliance and service industry machinery sectors.

ORBES-Regional Production

Projected differences in production by the major ORBES-region industries in the year 2000 under the two basic scenarios are presented in Table 5. Again, a positive difference shows greater dollar output under the FTF scenario; a negative difference, greater dollar output under the BOM scenario. In addition to wholesale and retail trade, the largest industries in the ORBES

TABLE 5. SCENARIO EFFECTS ON OUTPUTS OF MAJOR INDUSTRIES, ORBES REGION, 2000
(9 of 185 sectors)

Industry	$\left[\frac{FTF - BOM}{\frac{FTF + BOM}{2}}\right]\%$*
household appliances	7
service industry machinery	3
retail trade	<1
motor vehicles and parts	1
petroleum refining	-2
steel	-5
structural metal products	-12
coal mining	-30
electric utilities	-65

SOURCE: Reference 4.

*A positive difference means greater dollar output under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater dollar output under the BOM scenarios relative to the FTF scenarios. Sectors are ranked in terms of the differential dollar output between the two basic options.

region include motor vehicles and parts, electric utilities, household appliances, steel, and petroleum refining. Of these, household appliances and electric utilities are affected directly by the assumptions of the two scenarios. Consequently they would display relatively large differences in outputs between the two energy-growth options--7 percent in the case of household appliances and 65 percent in the case of electric utilities. The latter is the greatest differential between the two energy-growth options.

Other important industries of the region would be affected indirectly by the ORBES scenarios, for example, steel and structural metal products. The lower production by these industries under the FTF scenarios relative to the BOM scenarios would be attributable primarily to lower investment expenditures by electric utilities. Similarly, although not included in Table 5, the output of the construction and mining equipment industry would be relatively lower under the FTF scenarios as a result of lower demands for coal. Impacts on the important nondurable goods industries of the region--grains, meat products, alcoholic beverages, and tobacco products--would not be significant.

As shown in Table 5, there would be a substantial differential in regional coal-mining production, 30 percent, between the high- and low-energy-growth options. The relatively low increases under the FTF scenarios would be primarily the result of slower growth in coal-fired electricity generation and lower projected outputs by the industrial chemicals, paper and paperboard mills, and steel industries, which are major consumers of coal. Similarly, the lower energy-demand projections of the FTF scenarios would be reflected in decreased relative outputs of petroleum refineries, a 2 percent differential between the two energy-growth options.

The 5 percent greater relative output of the steel industry under the high-energy-growth scenario would be primarily the result of increased investment purchases by the electric utilities. In addition, other major steel purchasers would show higher outputs and consequent increases in steel consumption. The structural metal products industry would experience similar impacts under the BOM scenarios, with a 12 percent differential in outputs expected.

On the other hand, under the low-energy-growth option, both the service industry machinery sector and the household appliance sector would show relative gains over the high-energy-growth option in the year 2000. Relative increases by the service industry machinery sector, approximately 3 percent, would be largely the result of sales for energy-conservation purposes. In addition, energy-conservation investments in goods from other sectors that purchase service industry machinery, such as household appliances and plumbing and heating equipment, would create increased demand for this equipment.

The household appliance sector would have the largest production increase of all industries under the low-energy-growth option, approximately 7 percent. The greater output levels for this industry would reflect expenditures on appliances with higher energy efficiencies, with both higher costs per unit and higher replacement rates increasing these expenditures. Regional differences in outputs for retail trade and motor vehicles and parts would appear to be negligible. Some major local differences within the various states, however, could exist.

ELECTRIC UTILITY CAPITAL

In recent years, many forces have affected the costs of generating electricity. For example, environmental controls affect the cost of coal-fired plants, and requirements for safety systems affect investments in nuclear-fueled installations. Future directions are not clear-cut, but specific estimates of outlays were attempted, using historic costs in conjunction with recent trends. Investment costs for the power plants projected in the ORBES scenarios were extended from another study spanning the same time period as the scenarios, 1975-2000, in which the fuel mix projected was close to that of the BOM 50/50 scenario. Results were confirmed by adapting construction costs for fossil- and nuclear-fueled power plants estimated by a firm specializing in utility construction. Although the calculations in this section cannot be entirely precise, they do indicate relative scenario impacts on regional and national money markets (6).

Striking differences are evident among the scenarios. Either BOM scenario would require the utilities to be even more active participants than they are today in the very competitive national debt and equity money markets; they would need to seek an even greater share of available capital. Taking into account power plant construction, pollution control, general expenses, and transmission and distribution--all costs borne by the utilities--between 1975 and 2000 the BOM 50/50 scenario would require nearly $350 billion of capital investment in current dollars; the BOM 80/20, more than $300 billion. In contrast, the low-energy-growth scenarios would require approximately $70 billion (FTF 100 percent nuclear) and more than $50 billion (FTF 100 percent coal) (see Appendix H).

Coal and uranium mining capitalization required to meet ORBES scenario needs also was estimated. About 60 percent of the cost of producing coal can be translated to capital investment. Capital investment for uranium mining is more variable, depending on such factors as the type of mining (open pit or underground), the depth-to-vein thickness of the ore, its percentage of yellowcake (U_3O_8), production rate, exploratory and developmental drilling, hauling distance, milling operation, and, above all, current or expected yellowcake prices.

To estimate coal-mining capital requirements under the scenarios, an average mine size producing 3 million tons per year and requiring about $20 per ton of annual production for investment capital was assumed. The cumulative estimated capital for coal mines to the year 2000, proportional to production needs, would be approximately $10 billion in current dollars for the BOM 80/20 scenario; $7 billion for the BOM 50/50; $2 billion for the FTF 100 percent coal; and $1.5 billion for the FTF 100 percent nuclear (6).

Because of the concentration of energy in uranium ore, capital requirements for uranium mining are lower than for coal mining, although these requirements are expected to increase. The investment capital needed for uranium mining under the scenarios was determined by averaging underground and open-pit mining costs for a moderate-size mine producing 3000 tons of 0.1 percent U_3O_8 ore per day. The cumulative estimated capital requirements to the year 2000 would be about $7.5 billion in current dollars for the BOM

50/50 scenario; $3.5 billion for the BOM 80/20; $1.5 billion for the FTF 100 percent nuclear; and $1 billion for the FTF 100 percent coal (5) (see Appendix H). Capital required for coal and uranium mining combined would be about 10 percent of that required for power-plant construction.

Not included in these estimates are the investment and operating costs of enrichment facilities to make uranium a usable fuel.

LABOR

National Employment

As discussed below, on a national basis little difference in total employment between the high- and low-energy-growth scenarios would be expected. Within industrial sectors, however, there would be large variations in employment figures that would be reflected in the ORBES region. Of particular interest is the potential for regional labor shortages in the electric utility and mining sectors under the high-energy-growth option.

Most of the differential in jobs in the year 2000 between the low- and the high-energy-growth options would lie within the industries supplying investment goods to electric utilities and within the utilities themselves. As shown in Table 6, there would be a relative differential of 64 percent of the BOM over the FTF scenarios in persons employed in electric utilities.

In the year 2000, the 30 percent differential in national coal-mining production of the high-energy-growth option over the low-energy-growth option (see Table 4) would result in a 15 percent differential in the number of mining jobs; for railroad employment, the differential would be 5 percent. Sectors in which an employment differential of the FTF over the BOM scenarios would be expected are natural gas, water, and sewer services (a relative gain of 5 percent) and industries supplying goods for energy conservation: the household appliances, service industry machinery, plywood and millwork, plumbing and heating, and stone and clay products sectors.

These national employment differentials of the low- over the high-energy-growth option would be more than offset by differentials of the high- over the low-energy-growth option in the electric utility sector (64 percent) and the mining sector (15 percent). Relative differentials in other industries would be the result of lower demands for coal and electricity under the low-energy-growth option. These industries include railroads, railroad equipment, and structural metal products (4).

ORBES-Regional Employment

Under the scenarios most of the projected changes in labor needs would fall into three employment categories: coal mining, direct power plant construction, and plant operations and maintenance. Projections in these three categories were made to assess scenario impacts on the regional labor market.

TABLE 6. SCENARIO EFFECTS ON NATIONAL EMPLOYMENT, 2000
(20 of 96 sectors)

Rank	Sector	$\left[\frac{\text{FTF - BOM}}{\frac{\text{FTF + BOM}}{2}}\right]\%$[*]
1	household appliances	7
2	natural gas, water, and sewer	5
3	service industry machinery	3
4	electric apparatus, motors	3
5	plywood, millwork, structures	3
6	plumbing and heating	2
7	stone and clay products	2
8	construction	2
9	construction, mining, material handling machinery	<1
86	office, computing machinery	-1
87	structural metal products	-1
88	other transport	-2
89	petroleum refining	-2
90	petroleum and gas	-3
91	mechanical measuring devices	-5
92	locomotives, railroad and street cars	-5
93	railroads	-5
94	general industrial machinery	-6
95	mining	-15
96	electric utilities	-64
	all industries	<1

SOURCE: Reference 4.

[*] A positive difference means greater employment under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM option; a negative difference means greater employment under the BOM scenarios relative to the FTF scenarios. Sectors are ranked in terms of the differential in employment between the two options.

In regard to labor demand, the high-energy-growth scenarios imply a large growth in the proportion of construction activity devoted to power plant construction. Approximately 2.7 percent of contract construction employment in the United States is devoted to power plant construction. In 1974 total construction employment in the four ORBES states (not just the study region) was 493,000. Applying the national ratio to the ORBES states, more than 13,000 people in the construction industry (not all of whom were construction workers) were employed in power plant construction in these states in 1974.

Even assuming in-state mobility and no energy construction activity in the non-ORBES portions of the four states, the BOM scenarios would call for at least a 150 percent increase in direct construction labor requirements. To fire the coal plants under the BOM 80/20 scenario, about a two-thirds increase in coal-mining manpower would be required. Needs for operations-and-maintenance personnel also would increase substantially under both BOM scenarios. On the other hand, few major problems would be anticipated under the low-energy-growth scenarios. These potential effects are described in greater detail below.

Labor supply also was analyzed; it was found that the construction workers required under the scenarios might not be available. As shown below, this problem would be more severe under the BOM than the FTF scenarios in regard to both numbers of workers required and the scheduling of plant construction and consequent labor demand.

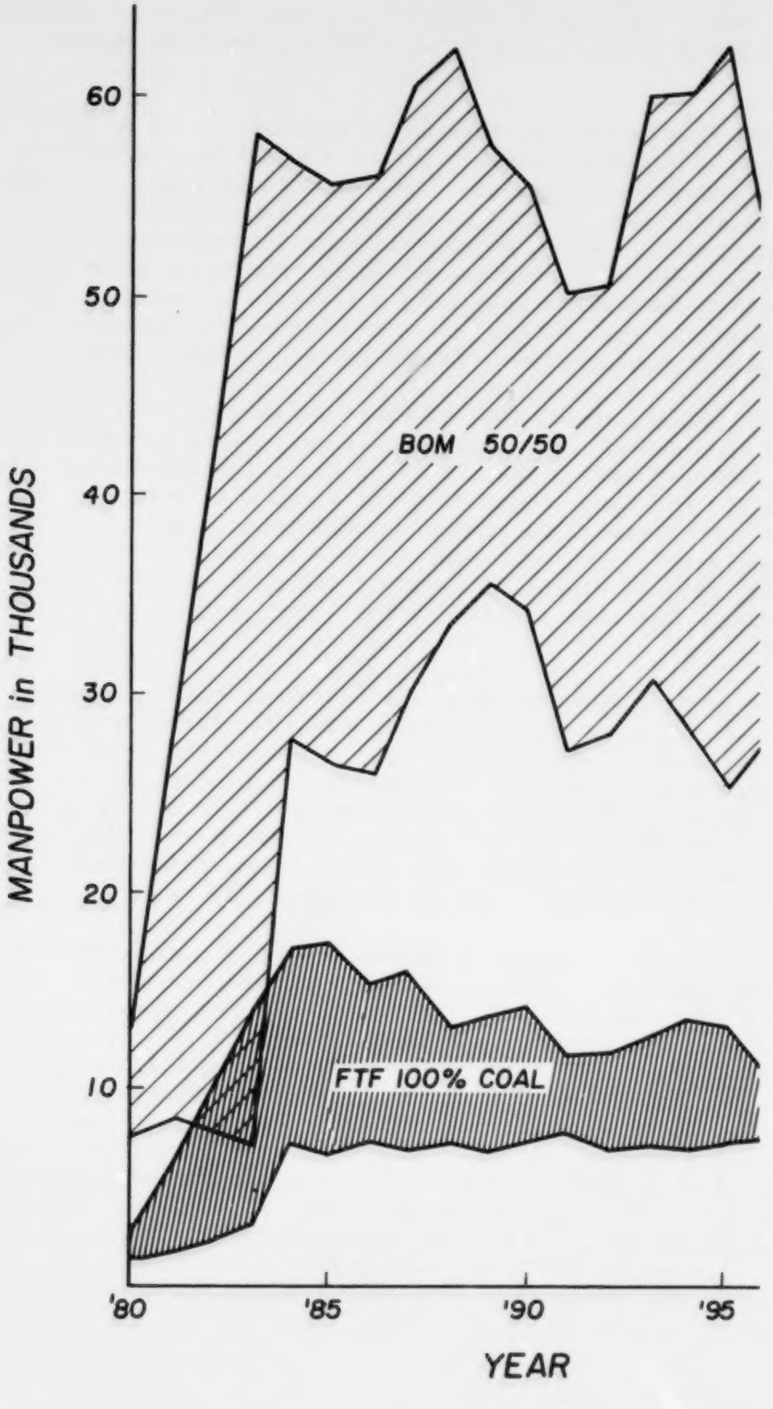
Coal-Mining Manpower. To estimate the additional number of coal miners required under the two BOM scenarios and the FTF 100 percent coal scenario, several assumptions were made, some of them modified from overall ORBES assumptions. Under all three of these scenarios, requirements for coal-mining manpower would increase. The increase would be greatest under the BOM 80/20 scenario--approximately 58,000 additional workers would be needed in the year 2000, about a two-thirds increase from the approximately 87,000 workers who were employed in coal mining in the ORBES region in 1975. Under the FTF 100 percent coal scenario, labor requirements would be considerably lower, with about 15,000 new workers needed (12).

Direct Construction Manpower. Under each BOM scenario, approximately 160 new electrical generating facilities would be constructed and on-line between 1986 and 2000. The major impact would occur in the construction occupations, which, in the short run, tend to be unresponsive to changes in manpower demand. Under such conditions, increased wage levels would be expected.

Of primary concern in assessing construction labor demands under the scenarios are both the level of demand for this labor and the timing of plant construction. When the level of demand is low and the timing of construction requiring additional labor does not indicate abrupt changes in demand for this labor, the overall impact is low. Under such conditions, the labor market would be capable of supplying requirements without driving up relative wages and consequently the cost of facility construction.

Two independent studies were conducted by ORBES researchers to assess the impact of the scenarios on the labor market (12, 13). These studies used similar methodologies to estimate construction labor requirements, as well as the same on-line dates for new plants, but each assumed somewhat different construction schedules. This led to different projections of annual direct construction requirements for each scenario (see Figure 2, depicting the range of requirements projected for the most and least labor-intensive scenarios, the BOM 50/50 and the FTF 100 percent coal). However, both sets of projections show similar long-term trends and differences among scenarios. Peak requirements, of course, would be higher for the BOM scenarios. Both studies found that the increased construction activity under the scenarios would lead

FIGURE 2. DIRECT CONSTRUCTION MANPOWER, TWO PROJECTIONS, BOM 50/50 AND FTF 100 PERCENT COAL SCENARIOS



to sharp initial increases in labor requirements; BOM requirements nearly would double between 1982 and 1983 and would rise by 300 percent between 1983 and 1984. It is difficult for the labor market to adjust to substantial shocks such as these. In reality, however, abrupt short-term changes in labor demand, such as those shown in Figure 2, probably would be smoothed over several years.

Both studies concluded that sufficient manpower would be available in most construction occupations to meet demand for all four scenarios. Under the high-energy-growth scenarios, however, drastic increases in demand would produce critical shortages in some occupations, such as boilermaking and pipefitting. These scenarios would require a large percentage of the increases in labor supply, a percentage considerably higher than historic averages. Construction of energy facilities uses only a fraction of overall construction labor. When viewed in this context of competition, the demands for skilled labor under the high-energy-growth option may be untenably high.

The FTF 100 percent coal scenario shows relatively slow adjustment to reasonably low requirements. In addition, requirements would be almost constant between 1986 and 1997. The FTF 100 percent nuclear scenario would reach a maximum construction labor requirement of 11,000, a level not substantially higher than estimated energy construction employment levels in the ORBES region in recent years. Indeed, under the FTF scenarios, direct construction employment would drop to approximately half its present level before it would begin to increase. Once the increase began, year-to-year change would be reasonably small.

Operations-and-Maintenance Manpower. The operations-and-maintenance personnel required under the various scenarios also were calculated by both of the studies discussed above. Both project approximately the same requirements. By 2000, operations-and-maintenance requirements for each of the BOM scenarios would rise to about 25,000 workers, slightly more than double the number under each of the FTF scenarios. Unlike the rate of change for construction labor, the employment increase for operations-and-maintenance manpower is generally smooth, and thus requirements would be satisfied more easily.

Labor Supply. The most difficult problems are found when examining the labor supply needed to meet the demand projected under the scenarios. Without doubt, the work force is aging. Large numbers of new workers would not be forthcoming to meet the needs of the scenarios. Much of the required future labor force has already been born; many of these potential workers are in school today. Declining school enrollments and apprenticeships in construction occupations, along with current fertility levels (see Chapter 6), are evidence that labor supply for the scenarios may be inadequate. Indeed, an analysis restricted to that portion of the labor force under 40 years old shows rapidly declining stocks of these workers after 1990. Between 1985 and 2000, labor requirements under the BOM scenarios would nearly equal or exceed the projected increase in the total number of new workers in the ORBES region. Even the FTF scenarios would require almost one-third the projected number of new workers (12).

The low-energy-growth scenarios are more feasible than the high-energy-growth scenarios in several respects. Of course, manpower requirements would be considerably lower--from about one-half to two-thirds lower for nearly all labor needs than under the high-energy-growth scenarios. In addition, projected manpower requirements for the FTF scenarios increase fairly smoothly. They lack the quick starts and extreme oscillations expected under the high-energy-growth option. Thus, despite the problems noted above, timing of labor demands under the low-energy-growth option would help ameliorate potential shortages.

ILLUSTRATIVE POLICY ISSUES

Transportation

--Does coal transportation in the ORBES region present enough of a problem that government at some level should promote the use of more efficient technologies such as regional coal-loading facilities?

--Should explicit or implied subsidies granted to private users of transportation facilities be modified or revoked so that these users pay the full costs of building and operating the facilities they use?

--In the development of new or expanding materials transportation systems, what balance should be struck between the free market, on the one hand, and government planning and regulation, on the other?

--Should taxes or materials transportation rate structures be adjusted to improve the efficiency of transportation systems?

--What should be the respective roles of federal, state, and local governments in regulating the transportation of high-level radioactive wastes within their respective jurisdictions?

--If it is demonstrated that some kinds of materials transportation systems have fewer adverse effects on the public than do others, what role should government have in encouraging the use or adoption of such systems?

Industrial Production

--Should the states or public intrastate bodies concern themselves with the availability and/or cost of coal for power plants?

--Should the states or public interstate bodies concern themselves with the availability and/or cost of uranium fuel for power plants?

--What steps can government take to encourage the coal industry to be more self-regulating in providing sufficient safeguards for workers' health and safety and in protecting the environment?

--What role should government play in the capital formation process by electric utilities?

--Electrical energy growth rates are difficult to forecast, and the resultant uncertainty has an adverse impact on the public sector. Given this situation, should it be the responsibility of government to forecast that rate, thereby assisting in the planning of energy-related facilities?

--Should rate structures for electricity recognize that increased future energy demand will require the construction of significantly more costly power plants than those currently in use, thereby raising the average per unit cost even when an individual consumer's demand remains constant?

Labor

--How might potential labor shortages for coal mining and power plant construction be averted through government action?

--What level or levels of government, if any, should assume responsibility for training coal-mining personnel and power plant construction workers to enter the work force?

--What role, if any, should government have in scheduling power plant construction to minimize labor shortages?

--What special programs, if any, should government develop for unemployed workers from energy-related occupations who might be affected by widely varying labor demands?

CHAPTER 5

IMPACTS ON THE BIOLOGICAL AND ECOLOGICAL ENVIRONMENT

The ORBES region has many unique climatological, biological, and ecological features and an abundance of resources, including land, water, limestone, and fossil fuels. These characteristics make the region attractive to a wide variety of interests, including industry and agriculture, and thus cause conflicts among such goals as preservation of the unique ecology, achievement of improved environmental quality, and maintenance of economic productivity. One of the principal inquiries of the ORBES project is the anticipated environmental consequences of the various scenarios and the policy issues raised by these consequences. This chapter examines the various air and water pollutants and their potential impacts on the nonhuman biological and ecological environment. Land quality also is examined in this chapter. Policy issues suggested by the various impacts appear at the end of the chapter. Public and occupational health impacts are considered in Chapter 6.

A major finding of ORBES Phase I is that all four air pollutants examined in detail would show significantly different rates of emission between the two basic energy-growth options in the year 2000. If nonpoint sources of water pollution are taken into account, significant differences also might be found in the concentrations of two of the four water pollutants examined. Another major finding was that if power plants continue to be built at preferred sites in the region, a dense pattern of these emission sources along river corridors would result. Because the directions of these corridors tend to be similar to persistent wind directions, pollutant concentrations would build up as the air mass moves downwind. It should be noted that a number of questions exist regarding the interactive effects among a number of power plants in an area of complex meteorological conditions such as the Ohio River Valley. Technological uncertainties are compounded by the presence of many political jurisdictions in a relatively small geographical area. Many of these questions and issues proved to be too complex to be dealt with adequately in ORBES Phase I, but they will be explored in detail during Phase II of the project.

AIR QUALITY

Over the past few decades, Congress has been paying increasing attention to the use of federal powers to protect and enhance air quality throughout the nation. The most recent and most important amendments to the Clean Air Act were made in 1970 and 1977. The fundamental concept behind these amendments is federal responsibility (assigned to the U.S. Environmental Protection Agency) to set national standards for ambient air quality and for the control of emissions from new sources of pollution. In partnership with the federal government, each state is responsible for developing specific plans to ensure that federal standards will be achieved in all areas of the state. Also, the air quality of current clean air areas may not be degraded by more than relatively small increments from current conditions, and special protection is given to selected federal lands (such as national parks). Through the use of national emission standards for new industrial sources of pollution, Congress intended that, as old sources are replaced by more strictly controlled new sources, air quality in industrialized areas would be improved beyond the requirements of the ambient standards.

The six air pollutants for which ambient standards have been set (criteria pollutants) are total suspended particulates, sulfur dioxide, nitrogen dioxide, hydrocarbons, photochemical oxidants, and carbon monoxide (14, 15, 16, 17, 18, 19). In addition, other potentially harmful compounds (such as sulfates) for which no standards have been set are formed through chemical transformations of criteria pollutants. In this section, the six criteria pollutants listed above are examined in the context of the ORBES scenarios, and their potential impacts on the nonhuman biological and ecological environment are discussed.

The EPA standards for short-term concentrations of criteria pollutants in the ambient air may not legally be exceeded more than once a year. (One of the assumptions made for the ORBES scenarios was that all standards promulgated as of 1976 will be met on schedule.) Two types of standards have been set for each of the six pollutants. Primary standards are intended to protect human health, while secondary standards are intended to protect the public welfare, defined as including property, soil, visibility, plants, animals, and other effects not related to human health. Each state has been required to develop a strategy to control emissions (called a state implementation plan) to meet the primary standards set by EPA. Currently states are not required to meet secondary standards within any specified period, although the Clean Air Act calls for these standards to be attained within "a reasonable time." In addition, new industrial sources are required to meet emission standards set for individual industrial source categories (new source performance standards). The emission forecasts presented in this section are based on new source performance standards for electrical generating facilities in existence in mid-1977. (These standards are now under review.) Finally, other continuous emission requirements, such as the prevention of significant deterioration, are utilized to control emissions on a local scale.

Table 7 presents a summary of the residual outputs of the major contributors to air quality degradation in the ORBES region in 1972 and as projected to 2000 under the scenarios; see Appendix I for breakdowns by state. Appendix I also contains an explanation of the methodology used in constructing the tables, data for which were taken from Reference 4.

The four pollutants examined in these tables are particulates, sulfur oxides, nitrogen oxides, and hydrocarbons. Photochemical oxidants (a principal component of smog) and carbon monoxide are not included in this aspect of the Phase I analysis because they are predominantly by-products of transportation. Some effects of these two pollutants, however, are discussed later in this section.

TABLE 7. MAJOR CONTRIBUTORS TO AIR POLLUTION, ORBES REGION

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total[*]	Percent of BOM 2000 total[*]	Percent change	Percent of FTF 2000 total[*]	Percent change	Percent difference $\left[\dfrac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%$[†]
Particulates	crushed stone	786	20	29	-35	30	-38	-4
	sintering	727	19					
	electric-coal-old	769	20	6	-88	6	-87	3
	electric-coal-new			7		5		-37
	industrial fossil fuels	440	11	9	-66	13	-51	36
	automobile travel			12		10		-31
	coal transporation-unit train			3				
	coal transportation-conventional train			7		8		-8
Total net		3927			-57		-59	-6
Sulfur oxides	petroleum refining	468	9	3	-66	3	-63	10
	electric-coal-old	3202	62	25	-57	22	-56	3

[*] Only sectors contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater emissions under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the FTF scenarios.

TABLE 7 (continued)

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total[*]	Percent of BOM 2000 total[*]	Percent change	Percent of FTF 2000 total[*]	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%$[†]
	electric-coal-new			39		25		-53
	industrial-fossil fuels	909	18	23	37	36	103	39
Total net		5150			7		-1	-8
Nitrogen oxides	electric-coal-old	736	34	12	-31	15	-29	3
	electric-coal-new			29		23		
	industrial-fossil fuels	340	16	8	3	14	74	51
	automobile travel	622	29	11	-30	9	-46	-31
	commercial truck	298	14	22	210	19	123	-36
Total net		2141			93		68	-14
Hydrocarbons	solvent-based paints	157	6	6	-39	9	-25	20
	service stations	216	8	14	5	13	-24	-32

[*] Only sectors contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater emissions under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the FTF scenarios.

TABLE 7 (continued)

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%$†
	automobile & personal truck use	1278	46	24	-69	25	-74	-20
	commercial truck	521	19	35	12	31	-22	-36
Total net		2768			-40		-58	-36

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[*] Only sectors contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater emissions under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the FTF scenarios.

As shown in Table 7 and as discussed in the following subsections, differences in emissions between the high-energy-growth (Bureau of Mines) scenarios and the low-energy-growth (Ford Technical Fix) scenarios in the year 2000 would be significant for all four of the air pollutants examined. The primary source of these differences is an assumed electrical energy conservation effort under the FTF scenarios, resulting in fewer power plants being built and thus fewer plant emissions under these scenarios. In order to both maintain gross national product and decrease consumption of electrical energy under the low-energy-growth option, however, industries are assumed to have developed their own local power sources. Thus, in the case of sulfur oxides, for example, the decrease in power plant emissions is offset in part by the resultant increase in the industrial combustion of fossil fuels.

Particulates

Particulates are defined in the EPA regulations as "any dispersed matter, solid or liquid, in which the individual aggregates are larger than single molecules (about 0.0002 microns in diameter), but smaller than about 500 microns" (14). Fine particulates (generally considered to be those less than about three microns in diameter) are of two types: primary (those emitted directly from industrial sources) and secondary (those formed by gas-to-particle conversion after the precursor gases are emitted into the atmosphere). (One micron is one-thousandth of a millimeter, or one millionth of a meter.) The major point sources of directly emitted, primary particulates in the ORBES region in 1972 were electric utilities, industrial combustion, steel, and the crushed stone industry, with quarrying and processing of crushed stone producing approximately 20 percent of the region's net particulates; coal-fired electric generating plants another 20 percent; sintering (application of heat without melting) plants about 19 percent; and the industrial combustion of fossil fuels approximately 11 percent (4). Uncontrolled (fugitive) emissions were not considered in this analysis.

Under both the low-energy-growth and the high-energy-growth options, net primary particulate emissions in the region for the year 2000 would decrease approximately 58 percent relative to 1972 emissions. These reductions are a result of the use of more efficient devices for the control of directly emitted particulates by industrial sources. Under the high-energy-growth BOM scenarios, however, there would be about 6 percent greater particulate emissions in the year 2000 than under the low-energy-growth FTF scenarios. Relative to 1972, primary particulates from the crushed stone industry would be reduced approximately 38 percent under the low-energy-growth option and 35 percent under the high-energy-growth option. This sector would produce a relative differential of about 4 percent greater particulates of the BOM scenarios over the FTF. Sintering no longer would contribute a significant portion of net primary particulate emissions under either the BOM or the FTF scenarios, about a 98 percent reduction from 1972 levels.

In the year 2000, direct emissions of net primary particulates from the industrial combustion of fossil fuels would decrease about 66 percent under the high-energy-growth option and about 51 percent under the low-energy-growth option relative to 1972, with about 36 percent greater emissions under the low-energy-growth option due to its increased emphasis on industrial coal use. Finally, net emissions from existing coal-fired electric plants would be reduced about 88 percent relative to 1972 levels under both the BOM and the FTF scenarios, due to plant retirement schedules and increased use of pollution control devices. However, new coal-fired plants would contribute an additional 7 percent of total particulate emissions under the BOM scenarios and an additional 5 percent under the FTF scenarios. The result would be an overall reduction in net primary particulates from electric generating plants relative to 1972 of about 70 percent for the high-energy-growth and 75 percent for the low-energy-growth scenarios, with the high-energy-growth option having 18 percent greater emissions in the year 2000 than the low-energy-growth option.

In addition to directly emitted primary particulates, secondary particulates also are important. They are formed by many atmospheric processes from gaseous compounds of sulfur, nitrogen, hydrocarbons, and photochemical oxidants. The secondary particulates of most concern are sulfates, which are primarily formed from sulfur dioxide.

Secondary particulates constitute from one-tenth to one-third of the mass of total suspended particulates normally found in the ORBES region. Except in the immediate vicinity of sources, they can be more important than the directly emitted, or primary, particulates. Regardless of their source, fine particulates have greater impacts on visibility, are more easily trapped in the human lung, and contribute more to acid rain than do coarse particulates. In addition, current pollution control devices are not as effective in controlling directly emitted fine particulates as they are for coarse particulates. However, unless equal attention is given to controlling the precursors of secondary particulates, there may not be significant overall improvements in air quality. In ORBES Phase I air quality modeling was limited to directly emitted, primary particulates; in Phase II the analysis will be expanded to include secondary particulates.

The chemical transformation of particulates in the atmosphere and their effects on receptors are not well understood. It is believed, however, that some particles may play an important role in the chemical transformation of gaseous pollutants into fine particulates, which can reduce visibility greatly. For example, a total suspended particulate concentration of 150 micrograms per cubic meter, with the dominant particles having diameters between 0.2 and 1 microns and with the relative humidity below 70 percent, will reduce visibility to five miles (8). Since current pollution control technology is effective against only primary particulates, the fraction of total suspended particulates contributed by fine particles is expected to increase, and visibility will continue to be a problem.

In addition to reducing visibility, directly emitted particulates cause plant damage in the immediate vicinity of their source by settling on leaf surfaces and forming undesirable deposits which could result in chlorosis, or the death of leaf tissues. In the case of alfalfa, even when there is no direct damage to leaves, the mere presence of particulate deposits on the leaves tends to reduce the market value of the product (20).

Sulfur Oxides

Sulfur dioxide, sulfur trioxide, and sulfates are the principal sulfur oxides emitted from stationary sources. In the ORBES region most of these oxides are produced by the burning of fuels with a high sulfur content. In general, 95 percent of the sulfur in high-sulfur eastern coal and in high-sulfur oil is converted to sulfur dioxide; for low-sulfur western coal this figure may be as low as 85 percent (21). Other sulfur oxide sources are the industrial and residential combustion of oil, petroleum refining, coke processing, sulfuric acid manufacturing, burning coal-refuse banks, and ore smelting. In 1972, petroleum refining contributed approximately 9 percent of the ORBES region's net sulfur oxide emissions, the industrial combustion of fossil fuels about 18 percent, and coal-fired power plants about 62 percent (4).

Sulfur oxide emissions under the high-energy-growth scenarios in the year 2000 would increase about 7 percent relative to 1972 levels. Under the low-energy-growth scenarios, levels would decrease by a small amount (about 1 percent). These increases would be primarily attributable to energy demand projections and the increased use of fossil fuels (as opposed to electricity) in industry. Overall, there would be a differential of about 8 percent in sulfur oxide emissions between scenarios in the year 2000.

Under the high-energy-growth option, emissions from existing coal-fired plants would decrease about 57 percent from 1972 levels due to plant retirement schedules and more efficient control measures. However, new plants would contribute another 39 percent of total net sulfur oxide emissions, for an overall increase over 1972 utility emissions of 11 percent. Under the low-energy-growth option, coal-fired electric utility emissions from existing plants would decrease approximately 56 percent from 1972 levels, while new plants would contribute 25 percent of total net sulfur oxide emissions in 2000--a regional decrease of 16 percent relative to 1972 levels. Overall, electric generating plants under the BOM scenarios would contribute approximately 28 percent more sulfur oxide emissions than under the FTF scenarios, due to the higher energy demand in the BOM. However, under the FTF scenarios, sulfur oxide emissions from the industrial combustion of fossil fuels would increase approximately 103 percent over 1972 levels, contributing about 36 percent of total regional emissions in 2000. Under the BOM scenarios, sulfur oxide levels from this sector would increase only about 37 percent relative to 1972, resulting in 39 percent greater industrial emissions under the FTF scenario.

Therefore, although through conservation the low-energy-growth scenarios would achieve a significant decrease in sulfur oxide emissions from electric generating plants, this decrease would be almost offset by the increase in emissions from the industrial combustion of fossil fuels under these scenarios. The result would be only a slight decrease (about 1 percent relative to 1972) in net regional sulfur oxide emissions in the year 2000, only 8 percent less than that projected under the high-energy-growth scenarios.

The mechanisms by which sulfur dioxide is oxidized to sulfates are not well understood but are important because they determine the formation rate and, to some extent, the final form of sulfates. Atmospheric sulfur dioxide may be oxidized to sulfur trioxide and converted to sulfuric acid aerosol, or it may form sulfite ions that are then oxidized to sulfate. After these oxidations, sulfuric acid or sulfate may interact with other substances to form other sulfate compounds. The rates of oxidation associated with these mechanisms can vary with humidity, temperature, sunlight, and concentrations of the reactants, such as ozone (22).

Atmospheric sulfur oxides have negative impacts on vegetation, animals, buildings, and visibility. When sulfur dioxide is absorbed by a plant, a sulfite is formed within the plant tissues which then is transformed slowly to sulfate. The intermediate sulfite is approximately 30 times more toxic to plant tissue than the resultant sulfate. Vegetation in the immediate vicinity of a sulfur dioxide source will be exposed to greater concentrations and is more likely to suffer acute injury (cell or tissue death) from toxic sulfite than is vegetation at a greater distance from the source that would be exposed to lower concentrations over a longer period of time. In the latter case, the absorbed sulfites can be transformed to less toxic sulfates (20).

Ambient sulfate particles reduce the penetration of sunlight necessary for photosynthesis and, at higher concentrations, may cause a reduction in primary plant productivity. Acid rains may cause acidification of surface waters, decreases in forest growth rates, and deterioration of building materials, as well as changes in predator-prey relationships, the leaching rates of soils and leaves, and the metabolic rate of organisms. The leaching of terrestrial systems increases eutrophication of surface waters and can cause a reduction in soil fertility and thus productivity. If the buffering capacity of the terrestrial systems is inadequate, this leaching can increase the acidity of surface waters, causing a marked decline in sport fisheries. Adverse impacts on plant populations will also affect animal populations that rely on the plants as a food source (5).

Nitrogen Oxides

Mobile sources, the industrial combustion of fossil fuels, and fuel combustion by electric utilities account for about 93 percent of the total emissions of nitrogen oxides. The major nitrogen oxide associated with combustion is nitric oxide, most of which is subsequently oxidized in the atmosphere to form the more toxic nitrogen dioxide. Under clean air conditions this conversion occurs at a relatively slow rate. In atmospheres containing reactive hydrocarbons or oxidants, however, the reaction accelerates greatly. In addition, nitrogen oxides may combine with amines to form nitrosamine compounds and with other organic materials in the atmosphere to form numerous photochemical oxidants such as ozone and peroxyacyl nitrates (PANs).

Within the ORBES region in 1972, coal-fired power plants emitted about 34 percent of the total net nitrogen oxide emissions, while the industrial combustion of fossil fuels emitted about 16 percent, automobile travel 29 percent, and commercial truck use 14 percent (4). In the year 2000 under the high-energy-growth option, net regional nitrogen oxide emissions would increase about 93 percent relative to 1972 levels. Under the low-energy-growth option, the increase would be about 68 percent. These increases are attributable to higher levels of nitrogen oxide emissions from industry, from electrical generation, and from commercial truck use. The latter two sectors would grow more quickly under the BOM scenarios than under the FTF, leading to about 14 percent greater nitrogen oxide emissions in the year 2000 under the high-energy-growth option.

Under the BOM scenarios, nitrogen oxide emissions from existing coal-fired electrical generation plants in the year 2000 would decrease about 31 percent relative to 1972 levels. New coal-fired plants would contribute 29 percent of total nitrogen oxide emissions, with the increase over 1972 levels about 130 percent. Under the FTF scenarios in the year 2000, emissions from existing plants would decrease about 29 percent relative to 1972, while new plants would account for 23 percent of total nitrogen oxide emissions--an overall increase in power plant emissions of about 85 percent over 1972 levels. The high-energy-growth option would have 21 percent greater emissions from electrical generating plants than would the low-energy-growth option. Nitrogen oxide emissions from the industrial combustion of fossil fuels would increase about 3 percent relative to 1972 under the BOM scenarios, but would increase 74 percent under the FTF scenarios. Overall, the low-energy-growth option would have 51 percent greater emissions from industrial combustion than would the high-energy-growth option, due to the assumed industrial shift from electricity to fossil fuels under the FTF.

For mobile sources in the year 2000, automobile travel under the BOM scenarios would contribute about 11 percent of total nitrogen oxide emissions, a 30 percent decrease from 1972 levels, while FTF emissions from automobile travel would decrease 46 percent, 9 percent of total nitrogen oxide emissions in 2000. Commercial truck emissions under the high-energy-growth option would increase 210 percent, for 22 percent of the total, while under the low-energy-growth option these emissions would increase 123 percent, 19 percent of the total. Overall, mobile sources under the BOM scenarios would generate 31 percent more nitrogen oxide emissions than under the FTF scenarios, due to an assumed increase in vehicle miles traveled under the BOM.

As with sulfur oxides, the lower nitrogen oxide emissions from power plants under the low-energy-growth scenarios than under the high-energy-growth scenarios would be offset to some extent by increases in industrial emissions. Because of contributions to emissions by the transportation sectors, the offset would not be as great as with sulfur oxides: under the high-energy-growth option there would be about 14 percent greater total nitrogen oxide emissions in the year 2000 than under the low-energy-growth option.

Nitrogen oxides cause objectionable atmospheric discolorations which may become severe at concentrations as low as several tenths of one part per million (ppm). They cause overt plant damage (cell or tissue death or chlorosis) at a few ppm and may result in a reduction in growth of as much as 35 percent at concentrations of 0.5 ppm or less over several weeks (23). In addition, nitrates are playing an increasingly important role in acid rainfall; the ratio of nitric acid to sulfuric acid in acid rainfall has been rising over the last 15 years.

Hydrocarbons

Hydrocarbon emissions in general, and polycyclic hydrocarbons in particular, originate primarily from the incomplete combustion of fossil fuels (as in coking ovens and the production of synthetic fuels) and from the use of hydrocarbons in such processed products as solvents. Reactions of hydrocarbons in urban atmospheres give rise to secondary contaminants and reaction intermediates that cause nearly all the detrimental effects of hydrocarbon air pollution. The polycyclic organic compounds (such as benzo(a)pyrene and dibenzo(a,i)pyrene) are believed to be the most toxic form of hydrocarbon emissions.

Sixty-five percent of all hydrocarbon emissions in the ORBES region in 1972 came from mobile sources, with 46 percent from automobile and personal truck use and 19 percent from commercial truck use. Another 8 percent originated at service stations; 6 percent can be traced to solvent-based paints. Fuel combustion from stationary sources contributed less than 2 percent of total 1972 hydrocarbon emissions (4).

Under the BOM and the FTF scenarios, in the year 2000 regional net hydrocarbon emissions relative to 1972 would decrease 40 percent and 58 percent, respectively, due in part to reductions in the use of solvent-based paints and controls on service station emissions, but more importantly due to more effective controls on automobiles and trucks. Overall, the BOM scenarios would have approximately 36 percent greater hydrocarbon emission levels in the year 2000 than the FTF scenarios, primarily due to the assumed increase in vehicle miles traveled under the BOM.

Under the high-energy-growth option, total transportation hydrocarbon emissions would decrease 45 percent from 1972 levels, to contribute 59 percent of the total emissions in the year 2000, 24 percent from automobile and personal truck travel and 35 percent from commercial truck use. Under the low-energy-growth option, total transportation emissions would decrease 58 percent relative to 1972, contributing 56 percent of the total regional emissions in 2000. Of this, automobile and personal truck emissions would make up 25 percent of the total; commercial truck use, 31 percent. Overall, the high-energy-growth scenarios would have about 26 percent greater hydrocarbon emissions in the year 2000 from transportation than would the low-energy-growth scenarios.

In the year 2000, service station hydrocarbon emissions would increase about 5 percent over 1972 levels under the BOM scenarios, while under the FTF scenarios they would decrease 24 percent. Finally, emissions traceable to solvent-based paints would decrease 39 percent from 1972 levels under the BOM scenarios and 25 percent under the FTF scenarios.

Thus the low-energy-growth option would result in significant decreases in hydrocarbon emissions relative to 1972 for all sectors, while under the high-energy-growth option only two sectors would show significant decreases. Overall, the BOM scenarios would result in 36 percent greater emissions from hydrocarbons in the year 2000 than would the FTF scenarios.

The principal direct effects of hydrocarbons and polycyclic organic compounds are on human health; these are discussed in Chapter 6. Their effects on animals and vegetation primarily are a result of the role played by hydrocarbons in the formation of photochemical oxidants, which is discussed in the following section.

Photochemical Oxidants

Photochemical oxidants (a principal constituent of smog) result from a complex series of atmospheric reactions initiated by the ultraviolet component of sunlight. These reactions convert nitrogen oxides and reactive organic substances (hydrocarbons) to new compounds such as ozone and peroxyacyl nitrates (PANs). Therefore, in order to control the more harmful photochemical oxidants, one must control their precursors--hydrocarbons and oxides of nitrogen.

During a 24-hour period of heavy smog in urban areas, ozone concentrations average about 0.15 to 0.2 parts per million and may peak at around 1 ppm. The ambient standard for ozone is 0.08 ppm for one hour. Extremely sensitive plant species, such as tobacco, show leaf damage at concentrations as low as 0.02 ppm. Toxicity experiments on animals have produced bronchitic pneumonia, edema, and death at concentrations ranging from 0.1 to 0.3 ppm. The effects of ozone are mitigated to some extent by an antagonism or cross-resistance between ozone and other toxic pollutants. For example, the presence of sulfur compounds such as hydrogen sulfide and sulfur dioxide, which are themselves toxic, has protected laboratory mice at ozone concentrations that otherwise would have been lethal (23).

Recent evidence strongly suggests that the precursors for oxidants that are emitted into the atmosphere of an urban area can be transported for many tens of miles into surrounding rural areas, where they can continue to react, thereby producing oxidant concentrations that exceed standards over a wide geographical area. These high oxidant concentrations are capable of accelerating the conversion of sulfur dioxide to sulfate particulates.

PANs, another critical element of photochemical smog, have been found to kill leaf tissues, to reduce the rate of water uptake by plants, to interfere with plant enzyme systems and cell wall metabolism, and to reduce blooming, fruit set, and overall growth rate in some species (23).

Carbon Monoxide

Carbon monoxide emissions result primarily from mobile sources. Thus they are primarily an urban problem that might be alleviated through transportation-control plans. Such considerations are not within the scope of ORBES.

Comparison of Regional and National Air Pollution Levels

Air pollution levels in the ORBES region are higher than would be expected if emissions were proportional to population. For example, while the region contains about 14 percent of the nation's population, particulate emissions are about 95 percent greater than what would be expected based on population. The major reason is the concentration of steel-processing plants and coal-fired electrical generating units in the region. While the steel sector (sintering) contributes only about 6 percent of national particulate emissions, it represents about 19 percent of the regional total.

In projections for the year 2000, regional net particulate emissions for both the high- and low-energy-growth options would be in line with national emissions of this pollutant. Regional sulfur oxide emissions, however, would be about 50 percent greater than expected under the FTF scenarios. These projected high levels are traceable to increased coal use: under the low-energy-growth option, coal-fired power plants are projected to contribute about 40 percent of national sulfur oxide emissions but almost 50 percent of regional emissions in the year 2000. Similarly, under that option, the industrial combustion of fossil fuels would contribute about 36 percent of regional sulfur oxide emissions but only about 20 percent of national emissions.

Under the BOM scenarios in the year 2000, higher emission levels than expected if emissions were proportional to population would be projected in the ORBES region for both nitrogen oxides and hydrocarbons--about 16 percent higher for each of these pollutants. Under the FTF scenarios, lower emission levels than expected would be projected for hydrocarbons (about 20 percent lower), while nitrogen oxide emission levels would be in line with projected levels nationwide. Combustion of coal by electric utilities and industries is the major source of nitrogen oxides (about 45 percent of regional emissions and 25 percent of national), while mobile sources, service stations, and petroleum refining account for most hydrocarbon emissions.

Current air pollution levels in the ORBES region also are higher than would be expected if emissions were proportional to land area. The region occupies about 4 percent of the nation's continental land area, but current emission levels exceed this 4 percent share by over 200 percent for all four pollutants examined. Similar trends hold when comparisons are made between projected national emissions in the year 2000 and those projected under the BOM and FTF scenarios.

Cascading Effect of Siting Corridors: Subregional Effects

In addition to the effects of the ORBES scenarios on regional and statewide air quality, potential local effects also were analyzed. Examination of the siting patterns for all four scenarios reveals heavy concentrations of new power plants along major rivers, particularly the Illinois and the Ohio. In order to examine the air quality impacts of these siting configurations, a theoretical model (the Air Quality Display Model) was implemented to determine the level of atmospheric pollutant concentrations if a persistent wind blew along any of these siting corridors (6).[1] In nearly all cases, the assumptions and approximations utilized in the application of this model resulted in figures that tend to underestimate these predicted concentrations. The model considered a corridor approximately 50 kilometers wide extending from Evansville, Indiana, to Cincinnati, Ohio. Fifty-eight power plants were assumed to be located within the corridor, following the siting configuration of the BOM 80/20 scenario. Calculations were made for a south wind (that is, a wind that originates from the south) blowing across the Ohio River siting corridor and for a west-southwest wind (that is, one coming from the west-southwest) blowing along the Ohio River siting corridor.

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[1] For a description of other ORBES research on pollutant transport modeling, see Reference 24.

Calculations made for a wind blowing along the Ohio River Valley (a west-southwest wind) showed that the maximum predicted 12-hour sulfur dioxide concentration in the corridor would be 598 micrograms per cubic meter ($\mu g/m^3$) for new plants built after 1985. This high concentration would be the result of a "cascading" effect. That is, as an air mass moves along the valley under persistent wind conditions, the emissions from each source would be retained in the air mass. Consequently, the pollutant concentrations would build up as the air mass passes each source in the siting corridor. This wind condition would be expected to occur once every two years. For the south wind blowing across the valley, the maximum anticipated 12-hour sulfur dioxide concentrations from new sources alone would be 554 $\mu g/m^3$. A persistent 12-hour southerly wind could occur between three and six times a year. See Figure 3 for a depiction of the siting corridors and the cascading effect.

It should be noted that no attempt was made to ascertain the contributions of present or anticipated sources to ground-level concentrations. Thus, as noted above, these predictions represent only the incremental contributions attributable to the siting of coal-fired plants *after 1985* for the BOM 80 percent coal/20 percent nuclear scenario. These conversion units would represent approximately two-thirds of the total electric generating capacity of the Ohio River Valley siting corridor in the year 2000. Since the new electric generating facilities would contribute only about 40 percent of the total sulfur dioxide emissions in the region in 2000 under the BOM 80/20, it is expected that the 12-hour sulfur dioxide concentration resulting from all sources (industrial and utility) would exceed 1000 $\mu g/m^3$ for either persistent wind. This would result in a 24-hour concentration in excess of 500 $\mu g/m^3$.

Under current EPA regulations, the allowable 24-hour sulfur dioxide concentration of 365 $\mu g/m^3$ may not legally be exceeded more than once in a year. As shown above, however, under the cascading effect of a south wind these allowable ambient concentrations could be exceeded three to six times a year. Another recent study has reported similar results (25, 26). It should be noted that ultimately the cascading effect would affect areas outside the ORBES region. For example, other recent research shows that the greatest impacts of acid rains will occur downwind--probably in the northeastern Appalachian Mountains (6).

A similar calculation for nitrogen oxide levels in the corridor for the south wind condition shows a maximum possible 12-hour incremental concentration of approximately 440 $\mu g/m^3$. Under the authority of the 1977 amendments to the Clean Air Act, currently EPA is drafting short-term nitrogen oxide standards.

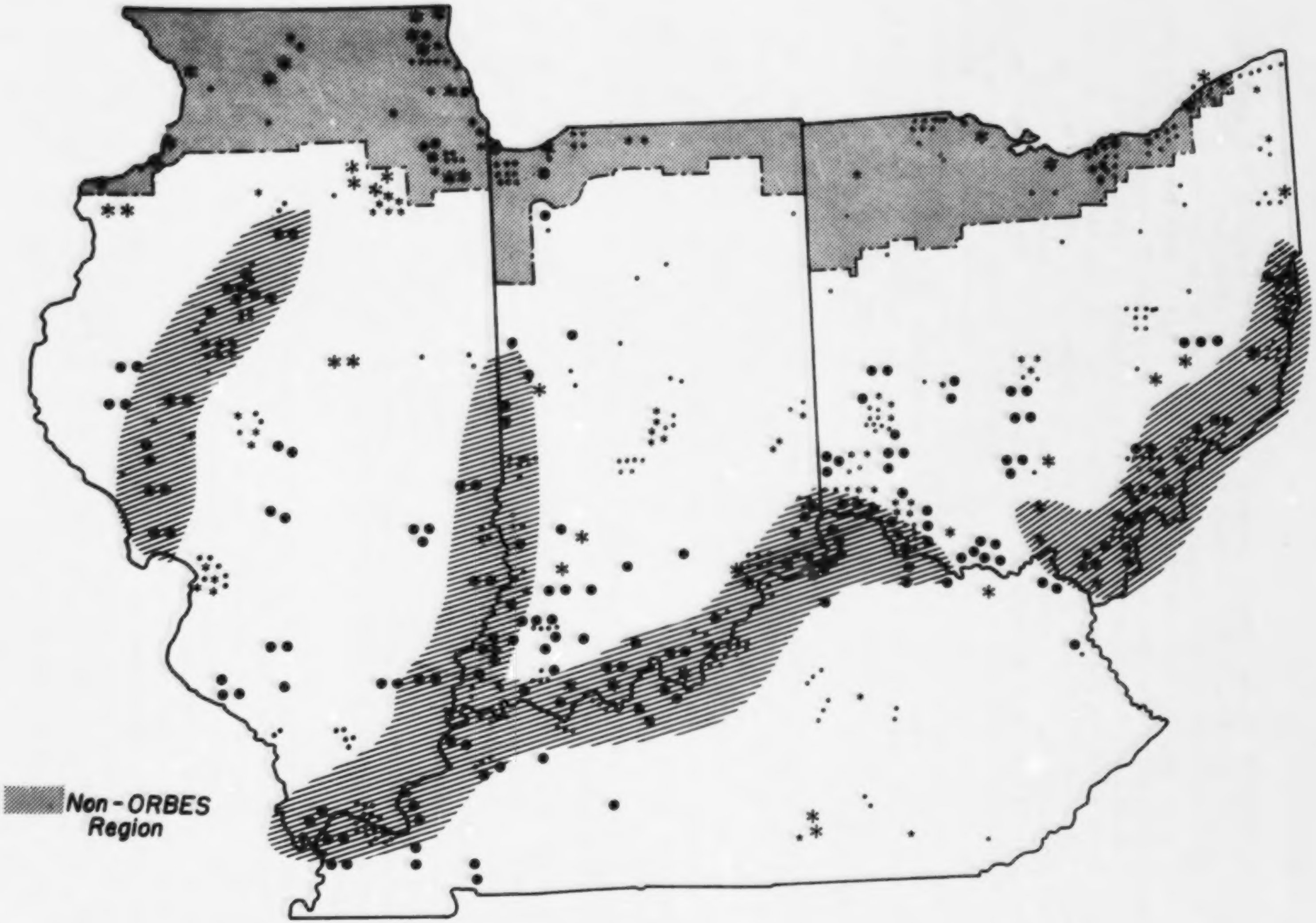
Non-ORBES Region

FIGURE 3. HIGH-DENSITY CORRIDORS RESULTING FROM SITING ALONG RIVERS

WATER QUALITY

In addition to using federal powers to protect and enhance air quality, in recent years Congress also has been directing its attention to water quality throughout the United States. In 1972, amendments to the Federal Water Pollution Control Act (FWPCA) were enacted. These amendments continued the existing requirement that states establish water quality standards for their interstate waters and broadened this requirement to include intrastate waters. Each state is responsible for classifying the desirable uses of its waters and for setting forth the pollutant concentrations that may not be exceeded in order for the standards to be met. The 1972 amendments also require that "effluent limitations" for point sources of discharge, set by the U.S. Environmental Protection Agency, be achieved. Set by industrial category (for 42 industries as of June 1977), the effluent limitations represent minimums that all dischargers in those categories must meet. The limitations generally require use of the best practicable control technology, to be achieved by 1977, and the best available control technology, to be achieved by 1983. If stricter limitations are necessary to achieve the water quality required by the state in its standards, they can be imposed.

The mechanism for ensuring that individual dischargers comply with the effluent limitations is the National Pollution Discharge Elimination System, also established by the 1972 amendments. Every facility that discharges effluents into navigable waters must receive a permit which includes, among other requirements, the effluent limitations that must be met. EPA has the authority to issue these permits but may delegate it to the states, retaining the authority to review permits. As of June 1977 in the ORBES-region states, Indiana and Ohio were responsible for administering their programs, while permits still were issued by EPA in Illinois and Kentucky.

The major effects of energy development on water quality stem from four pollutants: biological oxygen demand wastes (BOD), chemical oxygen demand wastes (COD), total suspended solids (TSS), and total dissolved solids (TDS). Also of importance are thermal discharges into streams, water consumption by electrical generating facilities, and the secondary effects of growth induced by energy facilities. See Table 8 for a summary of outputs of the major contributors to the four water pollutants named above in the ORBES region in 1972 and as projected to 2000 under the scenarios. Breakdowns by state appear in Appendix I.

As shown in Table 8, and as described in detail below, in the year 2000 there would be slightly more water pollution overall under the high-energy-growth BOM scenarios than under the low-energy-growth FTF scenarios, with some differences in concentrations found for all four of the pollutants examined. The major factors affecting these differences are the electrical energy conservation effort under the FTF scenarios and the greater emphasis on the use of coal under the BOM scenarios. It should be noted, however, that only point sources of water pollution (such as sewage plants) are taken into account. If nonpoint sources (such as agriculture) had been considered, significant differences between scenarios would be expected for two of the four pollutants examined: total dissolved solids and total suspended solids.

TABLE 8. MAJOR CONTRIBUTORS TO WATER POLLUTION, ORBES REGION

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%^{\dagger}$
BOD wastes	municipal sewage	103	36	52	-44	52	-44	
	plastic materials and resins	19	7	6	-63	6	-63	-.5
	citric acid	18	6					
	high-processing packinghouse	11	4					
	sulfite pulp	10	4					
	forest products & fisheries	7	3	13	95	13	93	-1
	canned & frozen fruits & vegetables			3		3		
Total net		284			-61		-61	-.4
COD wastes	forest produces & fisheries	43	15	37	44	38	42	-1
	plastic materials & resins	38	14	18	-22	18	-22	-.5

*Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

†A positive difference means greater effluents under the low-energy growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE 8 (continued)

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{\text{FTF-BOM}}{\frac{\text{FTF+BOM}}{2}}\right]\%^{\dagger}$
	citric acid	35	13	6	-73	6	-74	-.1
	meat animals & other livestock	22	8					
	industrial chemicals	19	7	6	-49	6	-50	-1
	dyes and dye intermediates	15	5	4	-60	4	-61	-.3
	synthetic rubber	13	5	3	-63	3	-63	-.7
	maleic anhydride	9	3	4	-25	4	-26	-.5
Total net		277			-40		-42	-3
Total suspended solids (TSS)	coal-other processing	4557	70					
	coal-metallurgical cleaning	1135	17					
	municipal sewage			47		48		
	electric-coal-old			7		8		15

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[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE 8 (continued)

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%^{\dagger}$
	electric-coal-new			8		6		-31
	coal-strip mined			6		5		-8
	plastic materials & resins			9		9		-.5
	forest products & fisheries			3		3		-1
Total net		6485			-98		-98	-3
Total dissolved solids (TDS)	citric acid	1154	51	62	129	60	129	-.1
	electric-coal-old	239	11	2	-61	2	-59	3
	electric-coal-new			6		5		-34
	coal-underground	83	4	4	95	4	76	-11
	coal-strip mined	321	14	15	93	13	78	-8

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[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE 8 (continued)

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%$[†]
	coal-other processing	68	3					
Total net		2242			84		78	-3

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[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

Water Consumption

Although water resources in the ORBES region are relatively abundant, anticipated growth in population, industry, and energy development will lead to increased demands for these finite resources. Much of this demand will be for "consumption" of water, that is, for water which is not returned to the stream and is not available directly for other off-stream uses or for maintaining water quality. (Impacts of water consumption on water quantity are discussed in Chapter 3.)

Excessive water consumption can exacerbate existing water quality problems--or cause new ones--when decreased flow rates provide less water for the dilution of discharges, leading to higher concentrations of pollutants. For example, estimates of water consumption for the BOM scenarios are almost twice as high as those for the FTF scenarios. Consequently, it is anticipated that under the BOM scenarios the region would be more dependent on inflow from outside it and that there would be a greater risk of water quality problems than under the FTF scenarios (9).

Thermal Effluents

In general, the greatest thermal impact of energy development occurs during electrical generation. The amount of waste heat is dependent on fuel source and plant size. The environmental effects produced are dependent on the amount of waste heat, the type of cooling system, and the nature of receiving waters. A typical nuclear-fueled plant operates at 32 percent thermal efficiency and releases about 40 percent more waste heat to cooling water than does a comparably sized coal-fired plant, which operates at approximately 38 percent efficiency, but releases part of its waste heat with the flue gas up the stack. Once-through cooling increases thermal efficiency slightly, but it greatly increases the thermal energy discharged to a body of water. Consequently, cooling towers or specially constructed cooling ponds are required technology for most new power plants. Thus, thermal discharges should level off or decrease as plants with once-through cooling systems are retired.[2]

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[2] Ohio River Valley Water Sanitation Commission (ORSANCO) pollution control standards (1-70 and 2-70, November 1970) recommend that the aggregate heat-discharge rate, figured on the basis of discharge volume and temperature differential (temperature of discharge minus upstream river temperature), not exceed a calculated amount. These standards also recommend that in no case should the aggregate heat-discharge rate be of such magnitude as would result in more than a 5 degree Fahrenheit increase in river temperature. State thermal discharge standards generally agree with the ORSANCO standards. Federal standards for new generating units require the use of the best practicable technology that will greatly reduce the discharge of heat, except in those situations where it can be shown that the discharge would have no adverse effect on the biological balance of indigenous species.

Thermal discharges may directly affect fish populations and their migration and spawning habits, as well as other aquatic organisms. What may be of even greater concern is the entrainment and impingement in once-through cooling systems of phytoplankton, zooplankton, fish eggs, and larvae, a large proportion of which may be killed by thermal or mechanical stress. Reducing the biological stock of these organisms can at times have a significant effect upon biological oxygen demand downstream from the discharge point. In the impacted areas, species diversity would decrease while hardy species populations would increase. Algal bloom, especially the blue-green variety, and spareotilus blooms (sewage fungus) would increase, causing potential problems for municipal water-intake systems.

In addition, thermal discharges may affect water quality directly by increasing consumptive evaporation levels, which would result in decreased flow rates and therefore higher concentrations of pollutants. Heated effluents accelerate the consumption of dissolved oxygen by high biological oxygen demand (BOD) wastes, and, near sources, critical dissolved oxygen levels may be reached before the waste can be assimilated in a more diluted stream. Higher temperatures also would decrease the solubility of oxygen and would slow re-aeration rates. Also, many undesirable compounds increase in solubility with temperature, resulting in increased levels of total dissolved solids (8).

The thermal impacts described above would not be expected to occur under either the BOM or FTF scenarios, due to the assumption that the cooling technology for all new power plants would be evaporative cooling towers. See Chapter 3 for a discussion of the consumptive water losses that could result from the widespread use of this technology.

Organic and Chemical Effluents

The principal chemical pollutants for which EPA has set effluent limitations are total suspended solids, oil and grease, copper, iron, zinc, chromate, phosphorus, and chlorine, all of which are additives of treated water used in generating plant boilers or as cooling water. Also of importance are levels of total dissolved solids and of high biological and chemical oxygen demand wastes.

Biological Oxygen Demand. As shown in Table 8, 36 percent of the net levels of high-BOD wastes in the ORBES region in 1972 came from municipal sewage treatment plants, 7 percent from the plastic materials and resins sector, and 3 percent from forest products and fisheries. Other significant sources of residuals were citric acid production (6 percent),[3] high-processing packinghouses (4 percent), and sulfite pulp production (4 percent) (4). Under scenario projections for the year 2000, however, effluents from the last three sectors either would be controlled or would no longer contribute significant portions of net discharges.

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[3] Almost one-third of the national output of citric acid is produced by two plants located within the ORBES region.

Under both the high- and the low-energy-growth options, total regional net BOD wastes could decrease by about 61 percent from 1972 levels. Overall, there is less than 1 percent difference between the BOM and FTF scenarios in projected levels of BOD wastes. Both options show a decrease of 44 percent from 1972 levels in municipal sewage discharges of high-BOD wastes, a result of new secondary sewage-treatment plants being built by municipalities. BOD wastes from plastic materials and resins would decrease 63 percent relative to 1972 levels, making up 6 percent of the total under both scenarios. On the other hand, BOD effluents from the forest products and fisheries sector would increase by about 94 percent relative to 1972 under both the BOM and FTF scenarios.

Chemical Oxygen Demand. Major contributors to total regional net COD wastes in 1972 were forest products and fisheries (15 percent), plastic materials and resins (14 percent), citric acid production (13 percent), meat animals and other livestock (8 percent), and the combined industrial chemicals sector, consisting of the industrial chemicals, dye and dye intermediates, synthetic rubber, and maleic anhydride sectors (20 percent) (4).

Under both the high- and low-energy-growth options, in the year 2000 total regional COD wastes would be reduced approximately 41 percent from 1972 levels. Overall, the high-energy-growth option would produce about 3 percent higher COD waste levels than would the low-energy-growth option. All sectors except forest products and fisheries would decrease relative to 1972 levels under either option, and it is only in the forest products and fisheries sector that the outputs differ between scenarios by one percentage point or more.

Under either option, COD wastes from the plastic materials and resins sector in the year 2000 would decrease approximately 22 percent from 1972 levels, contributing about 18 percent of total COD wastes. Citric acid effluents would decrease approximately 73 percent from 1972 levels under both options, to make up about 6 percent of the regional total. The combined industrial chemicals sector would decrease about 52 percent relative to 1972, approximately 16 percent of the total. Under both options, COD wastes from forest products and fisheries would increase approximately 43 percent over 1972 levels, to make up about 37 percent of the regional total. Overall, in the year 2000 the BOM scenarios would produce about 3 percent higher COD waste levels than the FTF scenarios, due to greater output in the industrial chemicals and forest products and fisheries sectors under the BOM.

Total Suspended Solids. In 1972, 17 percent of the net regional levels of TSS from point sources originated with the metallurgical cleaning of coal, while 70 percent came from other coal processing (4). Under both the high- and low-energy-growth options in the year 2000, TSS levels from these two sectors would decrease, primarily through the control of effluents from coal-processing operations, and these sectors would not contribute to net TSS levels. Point-source TSS levels would be reduced 98 percent relative to 1972. Overall, the high-energy-growth scenarios would produce approximately 3 percent more suspended solids from point sources than would the low-energy-growth scenarios. The major reasons for this difference lie in the greater number of coal-fired electric plants and the increased coal mining to supply those plants under the BOM scenarios. Unfortunately, no data are available on nonpoint sources that contribute to TSS (such as agriculture and urban runoff), even though this pollutant may stem primarily from these nonpoint sources.

Approximately 48 percent of the projected TSS effluents from point sources in the year 2000 would come from municipal sewage treatment plants, about 9 percent from the plastic materials and resins sector, and 3 percent from forest products and fisheries, with no significant difference between the scenarios for any of these sectors. Existing coal-fired electrical generating plants would contribute about 8 percent of total suspended solids under both the BOM and the FTF scenarios, with the BOM scenarios producing 15 percent greater TSS effluents in this sector than the FTF. Another 8 percent under the high-energy-growth option and 6 percent under the low-energy-growth option would come from new coal-fired plants, with 31 percent greater TSS effluents under the high-energy-growth option. The surface mining of coal would generate about 6 percent of total suspended solids under both options, with approximately 8 percent greater effluents under the BOM scenarios. Thus the higher level of energy development would increase sediment transport both directly, from strip mining, and indirectly, as induced growth, from agriculture and, as residuals, from point sources associated with power-plant ash or flue-gas scrubber sludges.

Sedimentation directly affects the cost and feasibility of water-resource projects by decreasing the life of reservoirs and necessitating larger projects than otherwise required to accommodate sediment build-up. Similarly, sedimentation increases the chance of flooding as well as the need for channel dredging; it affects fish populations directly by interfering with oxygen absorption. Sediment particles absorb metal ions, radionuclides, and other substances and release them into waters (27).

Total Dissolved Solids. Major point-source contributors to total regional net levels of dissolved solids in 1972 were citric acid production (51 percent), the surface mining of coal (14 percent), underground mining (4 percent), and coal-fired electrical generating plants (10 percent) (4).

Projections for the high-energy-growth scenarios show that regional TDS levels in the year 2000 would increase about 84 percent relative to 1972, while under the low-growth scenario net TDS would increase 78 percent. These increases can be traced directly to increased coal-mining activity, a result of ORBES scenario assumptions about fuel use, and to the production of citric acid, which is not responsive to scenario assumptions. Overall, the high-energy-growth option would have approximately 3 percent greater TDS levels in the year 2000 than would the low-energy-growth option.

Total dissolved solids from existing coal-fired electric plants would drop to about 2 percent under both scenarios, while new plants would add between 5 and 6 percent of this pollutant. The result would be an increase relative to 1972 in TDS effluents from all electric plants of 56 percent under the high-energy-growth option and 12 percent under the low-energy-growth. Overall, TDS effluents from the electric utility sector in the year 2000 would be 33 percent greater under the BOM scenarios than under the FTF.

The effects of high energy growth are reflected in the anticipated 95 percent increase over 1972 levels in TDS effluents from underground coal mining and in the projected 93 percent increase from surface mining. The low-energy-growth option would increase underground mine effluents by 76 percent and surface mine effluents by 78 percent relative to 1972 levels. Overall, in the year 2000 the BOM scenarios would have 11 percent higher TDS levels from underground coal mining, and 8 percent higher levels from surface mining, than would the FTF scenarios, due to the BOM emphasis on high energy growth and on coal.

The primary impact of coal mining on water quality comes from acid mine waters and their by-products. Sulfides in coal are acted upon by bacteria in the presence of oxygen and moisture to form sulfuric acid and iron salts. When discharged to streams, acid mine waters increase total dissolved solids, sulfates, iron, managnese, and hardness. These acid waters are corrosive and shorten the life of ordinary concrete and metals used in bridges, dams, pumps, turbines, and boats. In addition, the acidity levels of streams may become too high for many fish species to tolerate, while precipitated iron salts on stream bottoms may smother benthic and planktonic biota, disrupting food chains for fish, shellfish, and so forth.

Comparison of Regional and National Chemical Effluent Levels. Present BOD and COD waste levels in the ORBES region are lower than would be expected if effluents were proportional to the region's share of the national population--about 45 percent lower for BOD and about 40 percent lower for COD wastes. On the other hand, TSS and TDS discharges are higher than would be expected (about 200 percent and 20 percent, respectively). Some major contributors to national BOD and COD levels, such as feedlots, are not important ORBES-region industries. Instead, regional BOD loads come primarily from municipal sewage-treatment plants; COD loads, from a variety of other sectors. The discrepancies between ORBES-regional and national TSS and TDS levels are traceable directly to the concentration of coal-mining and processing activities within the region.

Projections for the year 2000 show essentially the same results for regional BOD and COD wastes as at present. Levels would remain well below those expected under both energy-growth options if these levels were proportional to population. TDS would remain above what would be expected if the national comparison held, with the regional share having risen due to the heavy concentration of coal-mining activities. For TSS, however, a substantial decrease in net residuals in the ORBES region by 2000 would be expected. This decrease can be traced to the abatement of residuals from coal processing within the region, as compared to a projected national increase in these residuals due to greater reliance on synthetic fuels.[4]

Water pollution levels in the ORBES region also were compared to those that would be expected if emissions were proportional to land area. In this comparison, only projected TSS levels would be below those expected. Levels of BOD, COD, and TDS would be well above those expected if the national-regional land ratio held.

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[4] See reference 28 for more information on synthetic fuel production.

COMPARISON OF AIR AND WATER QUALITY IMPACTS AMONG SECTORS

When gross and net residuals generation in the ORBES region as projected to the year 2000 are compared for the four air pollutants examined, significant differences in output between the two energy-growth options are found for all four. No significant differences between the two options were found for the four water pollutants examined. However, if nonpoint sources of pollution such as runoff from disturbed land are taken into account, differences between the two energy-growth options would be expected for two of these pollutants, total suspended solids and total dissolved solids. Some of the patterns found are the direct result of differing scenario assumptions, while others stem from the impact of these assumptions on industrial production and the energy-supply network, including trends in a few key sectors that affect the entire ORBES region.

The largest single source of differences between the two options is the electric utility sector. In the BOM scenarios, recent trends of increasing electricity usage are extrapolated. In the FTF scenarios, on the other hand, electrical generation is viewed as a primary source of energy inefficiency in the economy, and attempts are made to slow its rate of growth as part of an overall conservation strategy. As a result, electrical generation in the year 2000 under the BOM scenarios would be almost twice as large as generation under the FTF. However, from an environmental standpoint, twice the electrical output does not imply that the residuals from air and water pollutants also would double. Some of the growth in electricity supply during the period 1986-2000 would come from nuclear reactors, which are not major contributors to "conventional" air and water pollutant discharges, even though they have their own special residuals problems. In addition, the projected coal-fired plants would employ more efficient pollution control devices and thus generate fewer residuals per unit output than does the current mix of electric utility plants. Under the BOM scenarios, utilities would still generate approximately 40 percent more residuals than utilities under the FTF scenarios. This would have a major impact on the total regional loadings of particulates, sulfur oxides, and hydrocarbons.

The projected lower levels of residuals from the electric utility sector under the low-energy-growth scenarios would be offset to varying degrees (depending on the pollutant) by increases in residuals from the industrial combustion of fossil fuels. That is, in order to both maintain gross national product and conserve electrical energy under the FTF scenarios, industries in the region would produce their own power directly through combustion of coal and natural gas. Although this direct combustion is more efficient and thus produces fewer residuals than does electric generation, the level of industrial combustion required to maintain GNP is high enough to have significant effects on residuals under the FTF scenarios. In particular, direct industrial combustion is a major source of net regional particulates, sulfur oxides, and nitrogen oxides.

On the other hand, the FTF scenarios would achieve substantial reductions in transportation energy use--about 27 percent in the year 2000. This decrease would occur because the increased vehicle-miles traveled would be more than offset by the much greater average efficiency of automobiles used in the FTF scenarios in the year 2000. Significant reductions in mobile source air emissions also would be achieved by more stringent emission controls. These changes would constitute the bulk of the FTF impact on hydrocarbon emissions. They also are a significant part of the low-energy-growth option's impact on nitrogen oxide emissions, even though these decreases would be offset by increases in other sectors, particularly new coal-fired power plants. Under the BOM scenarios, anticipated increases in nitrogen oxides for the year 2000 would stem primarily from emissions from new coal-fired plants and, to a lesser extent, from increased emissions from commercial trucks.

Scenario assumptions about the level and mix of energy demand and fuels also would lead to impacts on water quality through the effects of these assumptions on the outputs of the energy extraction, conversion, and distribution industries. Due to the projected emphasis on coal, under both options in the year 2000 coal mines and related operations like breaking, sizing, and cleaning would contribute approximately 6 percent of the net loading of suspended solids and 18 percent of dissolved solids. Overall, the coal-mining sector would experience about a 98 percent decline relative to 1972 in net TSS discharges under both options, while TDS levels from the coal-mining sector would increase 77 percent over 1972 levels under the FTF scenarios and 93 percent under the BOM scenarios.

Hydrocarbon emissions from service stations would decline because of the imposition of emission control systems on them. Emissions would decline in direct proportion to the amount of fuel used, and therefore they would be lower under the low-energy-growth option. Refinery emissions are proportional to the petroleum produced and inversely proportional to the degree of pollution control. Under the FTF scenarios, some users of petroleum would increase their demand over 1972 levels. For other sectors, including electric utilities and residential uses, a decrease in demand would be projected. Overall, however, relative to 1972, due to increased emission controls on petroleum refineries, there would be significant decreases in sulfur oxide emissions from these sources under either energy-growth option.

Finally, a number of significant residuals producers are not responsive to the scenario variables considered. Included within this category are citric acid production (a major source of TDS), forest products and fisheries (BOD and COD), crushed stone (particulates), and municipal sewage (BOD and TSS).

LAND QUALITY

The main impacts of energy development on land quality and geomorphology stem from waste disposal, conversion by-products, surface mining, and construction activities. Impacts stemming from land-use conflicts are discussed in Chapter 3.

Waste Disposal and Extraction

Solid wastes are produced in virtually every energy-related process. For example, the waste generated during the conversion of coal into electric energy totals about 1.75 tons of solid waste per ton of coal used if the coal comes from surface mines; about 0.9 tons of solid waste is generated per ton of underground coal. Historically, there has been little government regulation of the disposal of these mine wastes. In most cases they have been either stored near the mine site or graded back into the mined area. As a result, several hundred thousand acres of land in the region have been "orphaned." Recent federal surface-mining legislation and state action will change mine waste-disposal practices in the ORBES region in the near- and long-term future. It is too soon, however, to estimate how significant these changes will be.

Lime or limestone scrubber wastes accumulate in specially constructed ponds near generating stations. A 1000 MWe plant requires a 30-foot-deep disposal pond covering about 80 acres to store the fly-ash and scrubber sludge produced over a 30-year plant life (7). Procedures for returning these areas to productive uses are available, but generally not mandated.

Fewer solid waste-disposal sites are required for the nuclear fuel cycle than for coal, but their potential impacts on land quality may be greater. That is, nuclear wastes potentially require that a relatively small area of land be disrupted in perpetuity, while coal mine wastes require disruption of large areas of land for a relatively short period of time. The principal nuclear waste problem in the ORBES region probably will be the long-term storage of irradiated wastes from nuclear power plants at regional disposal sites. The ORBES region already has storage facilities for low-level wastes and is a candidate for high-level waste-disposal facilities. Technical and political problems have been experienced in connection with at least one of these low-level waste-disposal facilities. The potential for land quality degradation is serious if confinement is incomplete.

During extraction, processing, and waste disposal, direct modification of the shape of the land and the production of waste materials occurs continuously. Surface mining can result in temporary or permanent piles of unstable waste materials, disruption of surface drainage and of aquifer flow, and significant acceleration of erosion and subsequent sedimentation and acid mine drainage. Underground mining can result in subsidence, which deforms surface features and disrupts drainage systems; disruption of aquifers; acid mine drainage; and surface deposits of mining refuse. Practices required by existing and proposed regulations, such as siltation basins, diversion ditches, prompt regrading, and revegetation, may be capable of avoiding or substantially mitigating these impacts as they occur (6). However, analysis of the effects of these regulations is inconclusive. Such regulations will be examined in detail during ORBES Phase II.

Surface mining also destroys all existing habitats in the mined area. Although current regulations require reclamation and reestablishment of the vegetative cover, this is a lengthy process (it may take many centuries to reestablish a high-quality deciduous forest). During the time an area is being mined, wildlife move into other territories and alter predator-prey relations there. Early in the revegetation process the younger ecosystem is less diverse and tends to attract different species from those in the original ecosystem. If any unique areas are destroyed, it is unlikely that their ecosystems could be reestablished. Similar impacts result from construction activities and other surface disruptions (8, 13).

Conversion, Transportation, and Utilization

Geomorphological impacts associated with reshaping the landscape and the attendant disruption of drainage patterns and sedimentation and erosion rates result from all phases of the coal and nuclear fuel cycles. For conversion, transportation, and utilization, geomorphological impacts are most obvious and severe during construction activities. Off-site impacts also may occur during conversion and utilization: increased drainage density, reduced surface permeability, and reduced drainage cover resulting from paved-over areas may cause changes in surface-flow intensity which in turn may affect erosion and deposition rates at downstream locations (6). Land quality also may be degraded over large areas surrounding coal-fired plants as airborne pollutants settle to the ground. These impacts on productivity are discussed in the section on air quality above.

Impacts on land quality and geomorphology are difficult to quantify. However, in terms of probability of occurrence, duration, intensity, and geographical scale, the BOM scenarios would have more severe impacts than the FTF. In addition, it is anticipated that those scenarios that emphasize coal usually would have more severe immediate impacts than those that emphasize nuclear fuel.

ILLUSTRATIVE POLICY ISSUES

Air Quality

--Some secondary, unregulated pollutants are believed to have substantially adverse effects on human health, perhaps in some cases effects more adverse than those of their regulated precursor pollutants (for example, sulfates, which are not regulated, are thought to be more toxic than sulfur dioxide, which is subject to regulation). To what extent should these precursor pollutants be regulated to reduce the formation of their secondary pollutants while research proceeds on the health effects of these secondary pollutants?

--In some cases state and federal environmental protection agencies disagree as to what power plant emission rates should be allowed. What changes in procedures would help remove existing inefficiencies in administrative and legal procedures intended to resolve such disagreements?

--Is a regional institutional mechanism needed to control the siting of new fossil-fueled electrical generating plants in the ORBES region to avoid unacceptable regional- and subregional-scale environmental impacts (for example, the "cascading" effect of air pollutants)?

-What period of time is reasonable within which to meet and enforce the secondary air pollutant standards?

--It is probable that power plants and industrial development in the ORBES region will "capture" clean air allotments for up-valley and/or cross-river neighbors. Should a multistate regional institutional mechanism be responsible for allocating available clean air increments?

--Does low-level radiation emitted routinely from nuclear-fueled plants now operating (or to be constructed) represent enough of a health hazard to warrant attention by regulatory agencies? (also listed in Chapter 6)

--Does low-level radiation emitted routinely from coal-fired plants now operating (or to be constructed) represent enough of a health hazard to warrant attention by regulatory agencies? (also listed in Chapter 6)

--Should standards to reduce public health risks from continuous radioactive emissions by coal-fired and nuclear-fueled plants be applied equally to these two technologies? (also listed in Chapter 6)

Water Quality

--Should thermal control technologies other than wet cooling towers and cooling ponds be considered for use in the ORBES region?

--Will the best available technology 1983 discharge requirements of the Federal Water Pollution Control Act be sufficient to achieve acceptable water quality goals within the ORBES region, or should zero-discharge requirements be developed for selected industries?

--If a municipality believes that the quality of its drinking water might be affected adversely by a proposed power plant and that additional pretreatment facilities are necessary to reduce risks from such adverse effects, should the financial burden fall on the public or private sector?

--How can permitting procedures for new coal mines be improved in order to ensure that no acid mine drainage will occur? In cases where acid mine drainage is already occurring, how can the necessary treatment be guaranteed to continue over the many decades or centuries during which this drainage will take place?

Land Quality

--What should the roles of state and/or local governments be in reviewing and determining the final acceptability of sites for the long-term storage of radioactive wastes? What should be their roles in monitoring such sites? (also listed in Chapter 3)

--Procedures are available for returning acreage affected by lime or limestone scrubber sludges to productive uses. What criteria should guide whether this reclamation should occur? What level of government, if any, should assume responsibility to ensure that this reclamation takes place?

--Whose responsibility should it be to decommission nuclear power plants after their useful life has ended? On what sector should the financial burden fall?

--By what decision-making process can society best ensure the safe long-term storage of radioactive wastes? (also listed in Chapter 6)

CHAPTER 6

PUBLIC HEALTH, ECONOMIC, AND SOCIAL IMPACTS

Energy development has a wide variety of direct and indirect impacts--both positive and negative--on social and economic systems. These include an upgrading of economic conditions, occupational health risks of coal mining, and indirect effects on local political structures. Although some of these impacts can be identified easily as direct results of a particular energy facility, many are dependent on the personal preferences and values of individual members of the affected community. The latter are much less predictable. Still other impacts, such as nuclear accidents, apparently have a comparatively low probability of occurrence but nevertheless must be planned for due to their potentially catastrophic effects. In most cases, however, the uncertainties are so great that only the boundaries of the probable impacts, and of possible responses to them, can be identified. Most social impacts examined during ORBES Phase I were local, or site specific, rather than regional, or scenario specific, and their quantitative comparison by scenario was outside the scope of Phase I resources. Thus most of the comparisons presented in this chapter are qualitative. The discussion of potential impacts is followed by a list of pertinent policy issues.

PUBLIC HEALTH

During the first year of ORBES, time and other resource constraints severely limited the public and occupational health analysis. Therefore, this section is limited to a general overview of the potential impacts of energy facility development. During Phase II, much more emphasis will be placed on regional and scenario-specific impact analysis. However, large uncertainties arise in such areas as the effects of current control measures for coal-mine dust on the incidence of black lung disease and of acid sulfate aerosols on the incidence or aggravation of human respiratory and circulatory diseases. Studies of these problems are now being made by a number of research groups.

Both economic development, as the means, and prosperity, as the social goal, contribute to public health, and each can produce either beneficial or detrimental impacts. Directly and indirectly, energy transformation and utilization processes generate significant, complex impacts on health and well-being which can affect both workers in energy-related occupations and the general population. First-order impacts (those associated directly with the production of electric power) include occupational hazards of mining, air pollution, and nuclear accidents. Higher-order impacts associated with the production and utilization of electrical energy include the effects of induced growth and its economic ramifications: improved standards of living and other national goals, diseases of poverty, and diseases of affluence.

Mining

The occupational health impacts of surface and underground coal mining are fairly well documented; they include respiratory diseases and accidents caused by falls of the mine roof, face, or highwall; gas or dust explosions; and mechanical and electrical system accidents. Between 1941 and 1970, the percentage of total U.S. coal-mining accidents attributable to underground mines decreased from 91 percent to 80 percent, while the surface mine share increased from 9 percent to 20 percent. For all U.S. coal mines, there was an average of 1311 fatalities per year during 1941-1945, while during 1966-1970 the average was 246 fatalities per year. In 1970, there were 112 coal mine fatalities in the ORBES region (including 38 in one disaster at Hyden, Kentucky) and 200 fatalities nationwide (29). Since the creation in 1972 of the Mining Enforcement and Safety Administration to carry out provisions of federal coal mine safety legislation, fatalities have decreased dramatically. In 1976, the number of fatalities nationwide was 141; in the ORBES region, the number was 53 (30). (See Table 9, which also shows nonfatal coal mine injuries and injury frequency rates for the region and the nation.)

The most significant health risk for workers in underground mines and mechanical cleaning plants is coal workers' pneumoconiosis (CWP, or black lung), a respiratory disorder attributable to inhalation of coal-mine dust. Although the frequency of CWP is relatively low in comparison to other mining injuries, its severity in terms of workdays lost is comparable to that for explosions or cave-ins in underground mines and to falls of the overburden in surface mines (29). The magnitude of the CWP problem also is shown in the cost of this disease to government. In 1973 the federal government spent approximately $1 billion for CWP benefits to coal miners and dependents who qualified under 1969 and 1972 mine-safety legislation. In contrast, the value of the coal mined in 1973 was about $5 billion (31).

Although significant occupational hazards are associated with the mining of uranium, currently no uranium is mined in the ORBES region. Thus consideration of the effects of uranium mining was not central to the ORBES analysis.

Conversion

Particulate Emissions. Coal combustion releases significant amounts of respirable particles, which usually are considered to be those between 0.1 and 3 microns in diameter. These particulates can combine with other pollutants, causing multiple synergistic effects if inhaled or swallowed. That is, toxic impacts of irritants absorbed or adsorbed by or onto particulates are magnified by particles holding toxins close to sensitive tissues--for example, sulfur dioxide adsorbed onto particulates can be converted to sulfuric acid, a more potent irritant. Particulates containing silica may cause excess formation of fibrous tissue, leading to silicosis and pneumoconiosis. Such carcinogens as nickel, arsenic, chromium, and beryllium can be carried to lung tissue by particulates. If particles carrying lead, tellerium, mercury, arsenic, selenium, nickel, chromium, and vandium are inhaled and

TABLE 9. COAL MINE INJURIES AND INJURY FREQUENCY RATES, ORBES REGION AND THE UNITED STATES, 1976

	Disabling injuries			Nondisabling injuries		All injuries	
	Number		Frequency rate per million man-hours	Number	Frequency rate per million man-hours	Number	Frequency rate per million man-hours
	Fatal	Nonfatal					
Illinois	3	988	32.61	569	18.46	1560	51.07
Indiana	1	117	13.75	164	19.21	282	32.97
Kentucky	42*	1990	31.17	1912	29.84	3944	61.01
Ohio	7	681	23.43	391	13.58	1079	37.02
Total ORBES region	53	3776	30.73	3036	24.37	6865	55.10
Total U.S.	141	13,944	36.41	11,853	30.72	25,938	67.13

NOTE: Numbers of injuries shown include all injuries reported to the Mining Enforcement and Safety Administration. Frequecy rates are calculated using only those injuries from mines for which man-hours have been reported.

*Includes one major disaster (a single accident resulting in 5 or more fatalities) at the Scotia mine that resulted in 23 deaths.

SOURCE: Reference 30.

assimilated to the body, the nervous system can be affected directly. These trace metals are contained in fly ash, but current monitoring efforts are insufficient to indicate whether concentrations around sources such as power plants are high enough to cause concern. (Trace metals also may leach out of ash piles and sludge ponds near coal-fired plants into drinking water supplies if these piles or ponds are not constructed and maintained properly.) Particulates can be retained in the lungs for periods ranging from a half-life (the time required to remove half the particulates) of two weeks to months or even years. Particulate matter swallowed in mucous matter, alone or with other elements and compounds adsorbed onto its surface, may induce toxic activity in the digestive tract (32).

Currently, certain industries in the ORBES region emit more particulates than allowed under primary ambient health standards. Most of these plants are on compliance schedules that will reduce primary particulate emissions with electrostatic precipitators or other control devices. As discussed in Chapter 5, both the high- and low-energy-growth scenarios for the year 2000 would result in about 58 percent decreases in directly emitted particulates relative to 1972. These figures do not include secondary particulates, however, and more research on their projected ambient concentrations is required.

Sulfur Oxide Emissions. Although federal regulation of sulfur oxides applies only to sulfur dioxide emissions (see Chapter 5), recent studies show that sulfates in the ambient air are more likely to be responsible for adverse health effects. For example, animal studies suggest that sulfur dioxide alone is a mild respiratory irritant but that sulfates, especially submicron sulfuric acid mist, are more severe irritants. Similarly, epidemiological studies on human beings suggest a higher correlation between poor health and sulfur oxide particulates than between poor health and gaseous sulfur dioxide alone. Also, the combination of sulfur oxides with other pollutants increases the possibility of adverse health impacts. For example, recent research shows that workers exposed to sulfate aerosols in combination with oxides of nitrogen and hydrocarbon emissions are two to five times more likely to experience chronic respiratory disease symptoms than are similar age and smoking groups in the general population (32).

Even low sulfate levels are believed to lead to worsening symptoms among cardiopulmonary patients and increased incidences of asthma attacks, breathing impairment in children, and chronic adult bronchitis. Sulfate concentrations believed to be harmful are 9 to 15 micrograms per cubic meter over a 24-hour period and 6 to 10 $\mu g/m^3$ averaged over a year. Ambient sulfate concentrations range between 6 and 15 $\mu g/m^3$ in rural areas in the northeastern United States, while concentrations as high as 80 $\mu g/m^3$ have been recorded in industrialized areas. In the region east of the Mississippi River and north of South Carolina, the 1972 urban annual average sulfate concentration was 13.6 $\mu g/m^3$; the nonurban, 10.2 $\mu g/m^3$. Outside this region urban and nonurban sulfate concentrations were 7.9 and 4.4 $\mu g/m^3$, respectively (22).

Although no dose-response curve for atmospheric sulfates has been developed, current sulfate levels probably are within the potentially harmful range. As noted in Chapter 5, a 7 percent increase in sulfur dioxide emissions over 1972 levels is projected for the year 2000 under the high-energy-growth (Bureau of Mines) scenarios; under the low-energy-growth (Ford Technical Fix) scenarios a decrease of about 1 percent from 1972 levels is projected. It is probable that the increase under the BOM scenarios would exacerbate adverse health effects currently experienced as a result of the presence of and interactions between sulfur oxides and particulates. Under the FTF scenarios, the present situation probably would continue.

Nitrogen Oxide Emissions. Nitrogen oxides are produced by organic nitrogen compounds in coal and, during combustion, by the oxidation of this element in the atmosphere. Available data show that nitric oxide reduces ciliary action by thickening the mucous layer over the cilia, thereby reducing their ability to keep the respiratory tract clear of mucus and foreign substances. In addition, nitric oxide derivatives have been shown to be carcinogenic. Research on animals indicates that intermittent exposure to concentrations of 15 parts per million can cause irreversible emphysema-like conditions; upon such exposure inflammation occurs. Effects are not evident in human beings until several hours after exposure (32). Current federal air quality standards limit annual nitric oxide concentrations to less than .05 ppm; a standard for short-term concentrations is being developed.

Radioactive Emissions. There are two areas of concern about radioactive emissions associated with energy development. First are the predictable, low-level emissions that result from normal operations of both coal-fired and nuclear-fueled power plants. Second are the unanticipated releases from nuclear plants that can result from core melt-down, sabotage, improper disposal of radioactive wastes, and other unpredictable spills and accidents.

--*Low-level emissions.* Both coal-fired and nuclear-fueled power plants release small amounts of radioactivity routinely. The estimated yearly release from a 1000 MWe coal-fired plant ranges between .005 and 600 millicuries, depending on the concentrations of uranium, thorium, and other radionuclides found within the coal seam utilized. Most of this radioactivity appears as part of the fly ash, with the remainder in bottom ash and gaseous emissions. Studies have reported the same or greater routine radioactive emissions from coal-fired as from nuclear-fueled plants (8). The level of this radiation received by the general population is low in comparison to that received from a variety of natural sources, such as the sun, rocks, and soil, and still is low in comparison to that received from color television sets, X rays, and air travel.

The question of health hazards associated with small amounts of radioactivity emitted routinely from both coal-fired and nuclear-fueled plants is both complex and controversial. During the first year of ORBES conflicting arguments on this topic could not be resolved adequately. However, the issue clearly is significant and will be addressed directly during Phase II of the project.

--*Unanticipated releases.* Although the impacts from unanticipated releases of radiation could be catastrophic, the probability of a major release has been estimated to be low. The chief area of concern is nuclear reactor reliability, but it also is necessary to consider sabotage, theft of nuclear materials, and the disposal of high- and low-level nuclear waste materials (including mill tailings, the residue remaining after uranium ore is refined).

The issue of nuclear reactor safety has led to much public discussion, but only one research effort, the Nuclear Regulatory Commission's Rasmussen study (33), has attempted an in-depth, quantitative assessment of reactor safety and the probability of various accidents. Detailed critiques have been made of this work, but no other comprehensive study has been carried out.[1]

Of the many possible accidents that might occur in a nuclear power plant, a core melt-down is considered potentially the most serious. The Rasmussen report predicts that a core-melting accident of any size has a probability of about 1 in 20,000 per reactor per year. According to the report, a major core-melting accident predicted to cause 110 early fatalities, 300 early illnesses, and property damage of $3 billion, and which would necessitate decontamination of about 3200 square miles and relocation of the population over an area of about 250 square miles, has a probability of 1 in 100,000 per year for the first 100 reactors in operation. Critics of the Rasmussen report question many of the study's assumptions and claim that the probabilities it predicts are thus overly optimistic. Some also question the objectivity of the researchers. Also, the study does not consider such factors as human error and civil strife in the probabilities it predicts.

One set of assumptions made by the Rasmussen study concerns the reliability of emergency core cooling systems. At present the U.S. Department of Energy is conducting an active research program to obtain experimental evidence on the reliability of these systems.

Nuclear wastes generally are divided into two classes, high level and low level, depending on their radioactivity. Low-level wastes are generated by nuclear reactors and by research, medical, and industrial users of radioactive materials. High-level wastes are generated by nuclear reactors and the production of nuclear weapons. Currently, high-level wastes from nuclear power plants in the form of spent fuel rods are removed from the reactor core and held in storage at the reactor site for at least 150 days to allow the short-lived fraction of the radioactivity to die away. After this time, the wastes could be shipped immediately for permanent disposal or could be reprocessed, moved to another site for an additional period, and then shipped for permanent disposal. At present in the United States, however, there are no operating reprocessing centers and no permanent storage sites for high-level wastes. Thus, all spent fuel rods are being held in some type of interim storage, mostly at existing reactor sites. The long-term effects of high-level waste disposal are very uncertain.

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[1] The principal earlier study was conducted at Brookhaven National Laboratory for the U.S. Atomic Energy Commission before any commercial nuclear power plants were in operation. It considered the worst possible effects of core-melting accidents (34). Among the groups and agencies that have criticized the Rasmussen study are EPA, the American Physical Society, and the Union of Concerned Scientists (35, 36, 37).

Security is necessary throughout the nuclear fuel cycle to prevent sabotage. However, if no fuel is reprocessed, security problems are lessened because plutonium (from which bombs can be constructed) is not readily available in isolated form. The theft of spent fuel rods would not be very practical in terms of possible weapon fabrication: the spent fuel is so radioactive it requires special equipment to handle, and the plutonium it contains cannot be extracted without an elaborate facility. Thus, unless a nuclear fuel reprocessing center opens in the ORBES region, the question of the theft of nuclear material would not arise there, except for the plutonium that is contained in the spent fuel rods of light water reactors.

Sabotage of a nuclear power plant is possible but complicated. Nuclear plants are more difficult to penetrate than are normal industrial installations, and access to critical areas and components is controlled tightly. Further, nuclear plants are built with several containment systems to prevent radioactive releases. Determining the probability of a successful sabotage attempt would be difficult, but the maximum possible environmental consequences of a successful sabotage are known, even if the probabilities are not. They probably would not exceed the worst cases discussed in the Rasmussen report for a reactor core melt-down.

Higher-order Impacts. An individual's physical and mental health can be closely related to his economic status. Thus the economic consequences of energy development (such as an increase in standard of living) in turn can be associated with impacts on health. For example, recent experience shows that with expanding energy development and rising gross national product in the United States, the gap between low and high income levels has widened, even when the absolute standard of living of low-income individuals and families has increased. Thus there may actually be a relative decrease in economic standard of living in subsistence-level poverty areas (some of which are in the ORBES region). Some have argued that the economic consequences of energy development could result in generally poorer public health and, because of tensions brought about by frustrated expectations, an increase in stress-related health effects. At the opposite end of the spectrum, plentiful, low-priced (relative to income) energy resources may bring higher-order ramifications such as labor-saving devices, richer food and drink, and increased pace of living. In this context, the public health impacts of energy development might include obesity, heart disease, and stress-related conditions. Thus, economic growth brought about by energy development does not necessarily guarantee improved public health within any income group.

As noted above, it is not possible at this time to specify expected public health impacts of the ORBES scenarios. It is possible, however, to identify the anticipated boundaries of these effects for the year 2000 (see Table 10). It should be recognized, however, that the occupational disease rate of zero appearing on the table is unrealistically low. Overall, the high-energy-growth (Bureau of Mines) scenarios would result in about two-and-one-half times more premature deaths than the low-energy-growth (Ford Technical Fix) scenarios for the complete coal and nuclear fuel cycles, from extraction of coal and uranium through transportation, processing, conversion, and disposal.

TABLE 10: ENERGY-RELATED PREMATURE DEATHS, BY SCENARIO, 2000
(based on installed capacity)

	BOM 80/20		BOM 50/50		FTF 100% coal		FTF 100% nuclear	
	coal	nuclear	coal	nuclear	coal	nuclear	coal	nuclear
Occupational								
Total accidents	105-285	2-14	77-209	4-37	43-116	0-4	35-94	0-12
Total disease	0-681	0-17	0-502	1-40	0-281	0-4	0-224	1-10
Total accidents and disease	105-966	2-31	77-711	5-77	43-397	0-8	35-318	1-22
General public								
Total general public	314-21,646	0-6	232-15,963	1-14	129-8929	0-1	103-7126	0-4
Total occupational and general public	419-22,612	2-17	309-16,674	6-91	161-9230	0-9	138-7444	1-26
Scenario total	421-22,649		315-16,765		161-9239		139-7470	

SOURCE: Reference 38.

LOCAL ECONOMY

Economic impacts associated with power plant construction usually are site specific. The scope of the Phase I assessment did not allow these impacts to be assessed fully or quantified, but they will be evaluated during Phase II (see also Reference 39).

Direct local economic impacts during the construction of each power plant would include increases in local employment and in demands for public- and private-sector goods and services. When increases of this nature are overly sudden and sharp, and when they accompany an influx of new residents into an isolated, rural community, they tend to create "boomtown" conditions. Between 1000 and 2000 workers would be employed during the peak construction period of each plant, and local economic impacts would be proportional to the relative numbers of local workers, temporary residents, and commuters. These impacts could be severe if a majority of construction workers resided temporarily in communities near the sites, but even with a relatively stable population, some of the trends associated with boomtown conditions could occur. Most of the potential plant sites in the ORBES scenarios, however, are located close enough to population centers that severe boomtown problems would not be expected (40). Also, boomtown conditions are more likely to occur in conjunction with energy facilities of larger scale than those of the ORBES scenarios, such as a number of plants grouped in a "power park" or a power plant sited at a mine mouth.

Increases in demand for public services would begin during plant construction, but the tax revenues needed to offset the necessary expenditures usually would not be collected until the plant was nearly in operation. Typically, collection of these revenues lags from two to three years behind the time that maximum demands for service are made on a community. In addition, tax revenues might not accrue in the jurisdiction financing the services. That is, intercounty commuting may result in increased demands for services in a county other than the one where the facility will be located.

Within the ORBES region under the scenarios, the major stress on public services would be expected to result from the increased traffic brought about by plant construction. Water and sewage services also would be expected to present problems in the Appalachian portions of the region. The provision of housing for new community residents also could become a problem. The severity of these impacts would tend to increase with distance from metropolitan areas, with the greatest problems anticipated in rural counties over 75 miles from a standard metropolitan statistical area (SMSA) (13).

If the demand for private sector goods and services increases faster than does supply, this rapid change may cause temporary shortages, price rises, and inefficiences. To meet the new demands, there might be increased employment in the private sector, with the magnitude of the impact dependent on the number of temporary construction workers. As construction nears completion, the business community would have to adjust to the operational level of the power plant (about one-tenth of the workers required for construction). This assumes that no additional industrial growth brought about by the new energy facility has occurred. Often, however, when coupled with favorable local economic conditions such as increasing population and an adequate tax base, an energy facility attracts industry to an area. This secondary, or induced, growth normally occurs after the facility is in operation. In rural areas, a dramatic expansion of the tax base brought about by an energy facility may lead to lower tax rates, which in turn may serve to attract additional industry.

Unlike the growth that may take place during plant construction, induced industrial development can be a stabilizing factor in the local economy and may alleviate any boomtown conditions that might have occurred. That is, employment other than that for plant construction, both public and private, and resulting revenues may increase in response to demands for additional goods and services. The extent of the impact would depend on the degree to which the existing system could supply these goods and services, but also important would be the degree to which increased demands were met by expansion of local capacity during the construction phase. Without induced industrial development, a community that experienced economic expansion during plant construction could undergo economic contraction during the early operation phase. The permanent operating force of the plant would probably reside locally rather than commute.

SOCIAL AND INSTITUTIONAL FACTORS

In addition to the local economic effects of energy conversion facility development, a variety of social impacts can occur. Some are the result of changes in a community's demographic composition, while others are related to residents' perceptions of their quality of life. Within the ORBES region under the various scenarios, these social impacts could vary widely from community to community, influenced by regional population trends. Social impacts are discussed in the following subsections. A quantitative comparison of these impacts across scenarios was beyond the scope of ORBES Phase I.

Also of importance are the institutional arrangements to regulate energy facility development; these arrangements also are discussed below. Understanding such arrangements is crucial when considering the legal and political framework within which decisions on energy facility development are made.

Demographic Projections

According to most recent estimates, population in the ORBES region increased by an average of 0.6 percent annually between 1970 and 1975. Total regional population was about 18 million in 1975. Natural increase was the primary reason for this growth; other factors affecting population include age distribution and in- and out-migration. During 1970-1975, Kentucky gained some population through migration while Illinois, Indiana, and Ohio each lost between 2 and 3 percent of their population due to migration, at the same time that overall population increased. In 1975, approximately two-thirds of the regional population lived in SMSAs. However, since the 1960s population growth rates in metropolitan areas of the north-central states have declined, primarily because people are leaving central cities for the suburbs and--more recently--for rural areas, a trend that has accelerated since 1970. The distribution of recent population growth in the ORBES portions of Illinois, Indiana, and Ohio (all north-central states) confirms this decentralization trend. Even Kentucky's metropolitan areas had a net migration loss of 0.1 percent as compared to that state's net migration gains (8).

During ORBES Phase I, three preliminary sets of population projections were made for the study region (see Appendix J). The ORBES Task 1 projections were based on combined official state predictions (41); those of a project special study used a component approach employing a sensitivity analysis as a check (12); and those of the Kentucky Delphi Project assumed that the 1970-1975 birth, death, and migration rates within the region would remain constant through the year 2000 (8). Although the two latter sets of projections employed different methodologies, both used the fertility level projected by Series II of the U.S. Census--2.1 lifetime births per woman, a replacement level of reproduction. Given current population trends, this rate may be too high.

Although the three sets of projections for the year 2000 considered the loss of regional population due to out-migration, and two assumed only a replacement level of reproduction, all three estimate overall population increases due to changes in age distribution. The annual increase in regional population between 1975 and 2000 projected by the Task 1 report is 0.9 percent; by the special study, 0.6 percent; and by the Kentucky Delphi Project, 0.5 percent.

Demographic Change

Social impacts from new energy conversion facilities would result from shifts in migration patterns, population size, and selected population characteristics such as age distribution and sex ratio (6). Some impacts would occur in the planning stage (for example, if land acquisition for an energy conversion facility forces families to relocate), but the most significant and extensive impacts would occur during power plant construction and operation.

Employment in the construction and operation of energy conversion facilities is a direct cause of demographic change. During the planning and construction phases, employee numbers increase rapidly, and then decrease as the plant nears completion, with the number of employees varying by project type and size. The number of employees needed and the requisite distribution of their skills may bring newcomers from previously unrepresented social groups to the community. During the operating phase of all types of facilities, the number of employees is stable and remains relatively low. The extent to which these employment impacts could occur in the ORBES region depends on a number of factors, such as the difference in labor requirements between coal-fired and nuclear-fueled facilities. As noted above, few severe boomtown effects would be expected in the ORBES region. However, several areas within the region are susceptible to some of the trends associated with boomtowns.

Community Types and Attitudes

Major social impacts are associated with the individual feelings and perceptions of the residents of a community housing a new energy facility. The kinds of conditions that might be necessary for communities to be receptive to, and to be able to benefit from, the siting of energy conversion facilities have been examined, and candidate counties for energy facilities under the ORBES scenarios have been classified according to their most likely response to facility development. The conclusion from this part of the ORBES research was that, in general, communities that are urbanizing, are economically diversified, are close to large cities, and that also have relatively young populations probably will be most receptive to energy facility development. Those communities that also show increasing population are attractive to the secondary development that may accompany energy development. Such localities usually have the revenues, tax base, and economic system that enable them to avoid the boomtown syndrome during the construction phase of development and to benefit from secondary effects of the operating phase. Rural areas with a commuting labor force may also be able to withstand the construction phase with minimal impacts, but, due to an undiversified infrastructure, may fail to expand sufficiently to attract secondary industrial growth (40).

Apparently least able to contend with power plant development are poor, declining, isolated rural communities that are not large enough to house the construction labor force for a number of years. Under these circumstances, a classic boomtown effect could occur, with an influx of newcomers with heavy demands on services, transportation networks, housing, and recreational facilities. It appears that the result may be a decrease in quality of life for many community residents during the construction phase. These initial adverse impacts may cause the community to reject any further industrial development (40).

Public services are an arena for potential impacts arising from the presence of a new energy facility. Demands for certain services, either from new residents or from long-term residents with rising expectations, are likely to increase. If tax rates have to be raised to finance new or expanded public services, the result might be political disillusionment and dissatisfaction with local policy makers.

The pattern of conflict between community newcomers and long-term residents is well documented; the effects of this conflict could be felt in such areas as changes in levels of demands for social realignments. Nuclear plant siting could introduce a special element of controversy, evident in recent statewide referenda and local debates, that might polarize a community's attitudes and political groupings. Opposition to nuclear facilities usually is based on environmental, aesthetic, health, and safety considerations. In the ORBES region, such disputes would be most likely under both BOM scenarios and the FTF 100 percent nuclear scenario; they probably would involve related political issues such as local control over, versus centralization of, siting decision making.

The importance of such chains of events, should they occur in the ORBES region, could be to decrease the relative benefits of energy development to the long-term residents of jurisdictions with new energy conversion facilities. In particular, the long-term-resident poor and elderly, and other groups such as female heads of households, may bear a disproportionate burden of such impacts as inflated prices and increased property taxes. These groups are least likely to be able to compete successfully for new employment opportunities which indirectly or directly result from electrical generation, and they may leave the locality because of rising taxes, unemployment, or lack of alternative housing. On the other hand, other long-term residents may see a rise in the level of public services available to them due to increased support for local school districts, small businesses, and so forth.

It should be noted that these and other social impacts, which tend to be localized, are associated not only with the relative numbers of new residents in a community, but also with the different value systems they might introduce.

Quality of Life

Anything that affects the psychological, social, physical, or biological condition of people can be said to affect their quality of life. Thus the definition of quality of life necessarily is broad. In addition, it must take into account subtleties of the interactions among these conditions (for example, the effects of physical health on state of mind and social behavior). In general, all of the ecological features of the human community are included in the concept of quality of life.

Quality of life probably is the basis of most concern over the social effects of energy development. Such development can affect quality of life either positively or negatively, and personal preferences can influence the nature and degree of these impacts (42). Among the affected subareas of quality of life are aesthetics, land use (especially public recreational land), community industrialization, and economic standard of living. Questions of personal choice are especially prominent in aesthetics, although they also are involved in the other subareas. With increased electrical energy production comes land disturbance through mining, construction of large buildings and towers, and the stretching of long power lines across the landscape. In some regions communities may not be affected, but in others residents may be appalled by the replacement of natural wooded areas, hills, and valleys by power-plant-related structures. Also, power facilities may produce more atmospheric haze--in contrast to the relatively clear skies to which residents may have been accustomed. The cost of these and other aesthetic elements simply cannot be quantified, in part because the attribution of *costs* to them is a personal value judgement. Others would see benefits from structures they may find more attractive than those that existed previously.

Energy conversion facility development will affect existing land uses. A key social impact concerning land use is its effect on recreational land. In some communities, recreational land may be despoiled, with both social and financial results. One negative impact would be the absolute loss of land for outdoor activities; an alternative impact would be the replacement of one form of recreation for another (such as a reservoir for a free-flowing river). Although the financial impacts on the participants and on the industries and services that cater to them can be measured, the social impacts of foregone recreation opportunities can be compared only qualitatively.

The increased industrialization accompanying energy development often means a rise in communities' economic standard of living. This is not to say that the quality of life necessarily is improved. In certain areas, standards of living may be raised above poverty levels, thus improving the quality of life, but new problems may result from this change. Although a community may realize an increased economic base, its political structure may be inadequate to cope with this increase. Also, the relative prosperity may be accompanied by problems such as increased air and water pollution. Balancing such negative and positive consequences of energy development becomes a matter of the individual's and community's perceptions of quality of life.

Institutions

One part of the ORBES Phase I research effort involved an inventory of the governmental units at all levels with legal, regulatory, and/or advisory authority over energy facility development (5). Institutional accountability for energy development and its direct and indirect impacts is divided among federal, regional, state, and local departments and administrative agencies. The scope of authority ranges from legislation, rulemaking, adjudication, and the granting of permits at the federal level to the administration of zoning ordinances at the local level. Some of this regulatory authority can be interpreted as a response to complex administrative problems posed by energy development. For example, a one-stop permit system for energy facilities could be established at the state level in response to complaints about the time and resources required to obtain multiple permits from a variety of agencies. Similarly, creation of the new U.S. Department of Energy was, in part, a response to the administrative problems that occurred when over 25 separate federal departments and agencies had some jurisdiction over energy-related issues.

At the ORBES-regional level, the Ohio River Basin Commission and the Ohio River Valley Water Sanitation Commission (ORSANCO) were created to deal with problems shared by two or more states, the former under federal legislation and the latter by an interstate compact approved by Congress. Such regional entities primarily are responsible for long-range planning, including the coordination of planning efforts by all other relevant institutions, both public and private; they have little regulatory authority.

Not only the administrative structure of regulatory authority, but also its process, reveals how institutions have responded to the complexity of energy-related problems. The most prevalent regulatory patterns today are the rule-making and permit processes. In response to public complaints about the intricacies of these processes, extensive public participation procedures have been developed. These procedures may include written comment or oral testimony on proposed rules, permit applications, and environmental impact statements as well as participation in formal public hearings on the proposed rule or permit. However, these processes are criticized by the regulated industries for the delay and added expense they cause in the construction of an energy facility. They also are criticized by citizens who believe that the public's input is not considered seriously; some believe that the only real purpose of the procedures is to promote and license energy facilities (43).

The impacts of future energy development on institutional structures and processes in the ORBES region are difficult to anticipate. In the first place, institutions are tied inextricably to politics, and political impacts can be considered to be indirect effects more likely to occur in response to other social and environmental changes. That is, sometimes it is difficult to determine whether energy development has brought about an institutional reorientation or whether the reorientation affected the energy development. For example, the demographic impacts of energy facility development may lead to a more complex governmental structure which, in turn, may have more control over future energy development and its impacts on the community. In addition, regular elections introduce a break in continuity in policy decision making that makes it difficult to anticipate what the institutional responses to energy-related problems will be over the intermediate to long term.

It is possible, however, to identify some of the responses to decisions to site energy facilities. An affected community's demands for amelioration of a facility's impacts may lead to policy reorientation (through the election of different officials) and/or institutional reorganization. The affected public--at the community level--might demand a more effective role in making decisions on siting. There then might be a conflict between regional and local policy in this decision making: since many of the environmental, social, and economic impacts of energy facilities are site specific, local governments might demand increased control over siting decisions. On the other hand, as regional impacts of energy facilities (such as pollutant transport and water consumption) are identified, more people could demand a governmental siting mechanism at the regional, interstate level.

In differentiating among scenarios, it is clear that the more extensive the development, the greater the number and likelihood of institutional impacts. Moreover, coal-fired and nuclear-fueled facilities have different impacts in many areas--for example, the physical, environmental, social, and economic. Whether one type of impact will be more likely to lead to an institutional response than another is dependent on community reactions and current institutional policy and structure.

Scenario Comparison

Given their relatively local and subjective nature, it is difficult to compare many of the social impacts in a quantitative way. All that can be said currently in comparing institutional impacts across scenarios is that such impacts are more likely and more numerous as development increases.

The number of counties in which energy conversion facilities would be sited under the scenarios would range from 83 (BOM 80/20) to 15 (FTF 100 percent nuclear). The BOM 80/20, the scenario requiring the greatest land area, would call for over 50 percent more acreage for coal extraction and processing than would the FTF 100 percent nuclear, the scenario requiring the least land area (see Chapter 3). The BOM scenarios would employ about three times as many workers during peak construction as would the FTF scenarios (see Chapter 4). Thus, the potential for significant social impacts under the high-energy-growth option is high, especially given projected concentrations of facilities in contiguous counties in southeastern Indiana and southwestern Ohio. Most of these counties are either within a metropolitan area or within commuting range of one, however, and about half of them already are growing more rapidly than the subregional average. A few counties in southeastern Illinois and southwestern Indiana that were selected as sites for coal-fired facilities may have potential boomtown characteristics, but even these sites are within a two-hour drive of a metropolitan area.

Relocation of residents could result either from expansion of surface-mining areas or from acquisition of land for power-plant-related facilities. Impacts from the latter would be more significant under the BOM scenarios because these facilities were sited in the more densely populated counties. Surface mining would create the least need for relocation, considering the expected use and geographical distribution of coal reserves in the ORBES region. Even under the high-energy-growth option, however, a relatively small number of people would be involved.

The scale and intensity of social impacts under the FTF scenarios would be more local, and much less severe regionwide, than those under the BOM scenarios. In southeastern Ohio counties, anticipated social impacts would be similar to those expected under the BOM scenarios. However, there is a distinction between the FTF 100 percent nuclear scenario, in which facilities were assumed to be sited in counties with relatively high population growths and net migration gains, and the FTF 100 percent coal scenario, in which most candidate counties have a net migration loss. The social impacts of population growth and of migration patterns probably would be greater in the latter case.

ILLUSTRATIVE POLICY ISSUES

Public Health

--Which levels or groupings of governments (such as regions, or groups of states) should address the trade-offs between possible health abuse and the need for electrical energy production? Which levels or groupings should address the trade-offs between possible health abuse and increased employment from energy facilities? What institutional mechanisms would best facilitate such considerations?

--Should any governmental entity below the federal level have the power to forbid the siting of a nuclear waste-disposal facility within its boundaries, and if so, which level?

--Given the large uncertainties in the response of human beings to environmental pollution, are current procedures adequate for controlling exposure of the population to potentially harmful pollutants? What balance should be struck between controlling exposure to possibly harmful pollutants (such as sulfates) and the economic costs of control?

--Are the probability and consequences of unanticipated releases of radiation from nuclear power facilities in the ORBES region sufficient to justify joint planning by states or other government groupings to deal with such releases?

--Does low-level radiation emitted routinely from nuclear-fueled plants now operating (or to be constructed) represent enough of a health hazard to warrant attention by regulatory agencies? (also listed in Chapter 5)

--Does low-level radiation emitted routinely from coal-fired plants now operating (or to be constructed) represent enough of a health hazard to warrant attention by regulatory agencies? (also listed in Chapter 5)

--Should the same standards to reduce public health risks from continuous radioactive emissions by coal-fired and nuclear-fueled plants be applied equally to these two technologies? (also listed in Chapter 5)

--By what decision-making process can society best ensure the safe long-term containment of ratioactive wastes? (also listed in Chapter 5)

Local Economy

--Does the possibility of intercounty commuting of workers to power plants under construction in the ORBES region justify developing devices to help compensate those counties that must provide increased services but that may not receive additional revenue?

--What factors should be considered in apportioning tax revenues received from an energy facility between state and local governments?

Social and Institutional Factors

--Energy conversion facilities frequently are located close to small towns or communities with limited planning capabilities. What institutional mechanism could help these communities plan for and deal with the demands for services by an influx of construction workers?

--Should a regional, interstate power plant siting agency be established by governments in the ORBES region?

--What functional role should the local community have in power plant siting decisions?

--How should the trade-off be made between state and local autonomy, on the one hand, and regional energy-environmental problem solving, on the other?

--Are there ethical considerations to be taken into account in the development of energy facilities? If so, how can they best be addressed by government?

--Energy conservation achieved through reduction in new power plant construction apparently will result in relatively little improvement in sulfur oxide emission levels if the gross national product is maintained through transfer of natural and human resources to other forms of industry. How can economic development in the ORBES region be continued while at the same time a substantial reduction in pollution emissions is achieved?

REFERENCES

1. U.S. Congress, Appropriations Committee, 94th Congress, 1st Session, Senate. *Department of Housing and Urban Development-Independent Agencies,* Senate Report 940326, 1975.

2. W. G. Dupree, Jr., and John S. Corsentino. *United States Energy through the Year 2000* (revised). Bureau of Mines, U.S. Department of the Interior, Washington, D.C., December 1975.

3. *A Time to Choose: America's Energy Future.* Final Report, Energy Policy Project, Ford Foundation, Cambridge, Massachusetts, Ballinger, 1974.

4. Richard Meyer et al. *Impacts of Energy Development in the Ohio River Basin: Final Report.* Prepared for the U.S. Environmental Protection Agency. International Research and Technology Corporation, McLean, Virginia, September 12, 1977. Supplementary data were supplied by International Research and Technology Corporation.

5. Nicholas L. White and John F. Fitzgerald. *Legal Analysis of Institutional Accountability in the Ohio River Basin.* ORBES vol. III-E. Prepared for the U.S. Environmental Protection Agency, May 15, 1977.

6. University of Illinois. *Preliminary Technology Assessment Report.* ORBES vol. II-C. Prepared for the U.S. Environmental Protection Agency, May 15, 1977.

7. Thomas H. Pigford et al. "Fuel Cycles for Electric Power Generation." In: *Comprehensive Standards: The Power Generation Case.* Prepared for the U.S. Environmental Protection Agency. Teknekron, Inc., Berkeley, California, March 1975.

8. University of Kentucky and University of Louisville. *Preliminary Technology Assessment Report.* ORBES vol. II-B. Prepared for the U.S. Environmental Protection Agency, May 15, 1977.

9. E. Downey Brill, Jr., et al. *Issues Related to Water Allocation in the Lower Ohio River Basin.* ORBES vol. III-G. Prepared for the U.S. Environmental Protection Agency, May 15, 1977.

10. *Weekly Announcements.* U.S. Energy Research and Development Administration, week ending December 29, 1976.

11. Michael Rieber. *Energy Transportation/Distribution in the ORBES Region.* ORBES vol. III-F. Prepared for the U.S. Environmental Protection Agency, May 15, 1977.

12. Robert C. Dauffenbach and Thomas P. Milke. *Labor Demand Impact and Labor Market Feasibility of Energy Conversion Facilities in the Ohio River Basin.* ORBES vol. III-A. Prepared for the U.S. Environmental Protection Agency, May 15, 1977.

13. Indiana University, The Ohio State University, and Purdue University. *Preliminary Technology Assessment Report.* ORBES vol. II-A. Prepared for the U.S. Environmental Protection Agency, May 15, 1977.

14. *Air Quality Criteria for Particulate Matter.* AP-49. U.S. Department of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, National Air Pollution Control Administration, Washington, D.C., January 1969.

15. *Air Quality Criteria for Sulfur Oxides.* AP-50. U.S. Department of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, National Air Pollution Control Administration, Washington, D.C., January 1969.

16. *Air Quality Criteria for Nitrogen Oxides.* AP-84. Air Pollution Control Office, U.S. Environmental Protection Agency, Washington, D.C., January 1971.

17. *Air Quality Criteria for Hydrocarbons.* AP-64. U.S. Department of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, National Air Pollution Control Administration, Washington, D.C., March 1970.

18. *Air Quality Criteria for Photochemical Oxidants.* AP-63. U.S. Department of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, National Air Pollution Control Administration, Washington, D.C., March 1970.

19. *Air Quality Criteria for Carbon Monoxide.* AP-62. U.S. Department of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, National Air Pollution Control Administration, Washington, D.C., March 1970.

20. Ellis F. Darley. "Vegitation Damage from Air Pollution." In: *Combustion-generated Air Pollution,* Ernest S. Starkman, ed. Plenum Press, New York, 1971.

21. *Compilation of Air Pollutant Emission Factors.* 2d ed. Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Washington, D.C., April 1973 (bituminous), and supplements, December 1975 (lignite).

22. *Position Paper on Regulation of Atmospheric Sulfates.* EPA-420/2-75-007. U.S. Environmental Protection Agency, Washington, D.C., September 1975.

23. Joe O. Ledbetter. *Air Pollution.* Part A: *Analysis.* Marcel Dekker, New York, 1972.

24. R. E. Bailey et al. *Pollutant Transport Models for the ORBES Region.* ORBES vol. III-H. Prepared for the U.S. Environmental Protection Agency, May 15, 1977.

25. Lowell F. Smith and Brand L. Niemann. *The Ohio River Basin Energy Study: The Future of Air Resources and Other Factors Affecting Energy Development.* Paper prepared for presentation at the Third International Conference on Environmental Problems of the Extractive Industries, Dayton, Ohio, November 29-30 and December 1, 1977.

26. S. J. Gage et al. *Long-range Transport of* SO_x/MSO_4 *from the United States EPA/Teknekron Integrated Technology Assessment of Electric Utility Energy Systems.* Paper prepared for presentation at the International Symposium on Sulfur in the Atmosphere, Dubrovnik, Yugoslavia, September 7-14, 1977.

27. Clara A. Leuthart and Hugh T. Spencer. *Radionuclide and Metal Ion Content of Late Summer Ohio River Sediments: McAlpine Pool 1976.* ORBES vol. III-I. Prepared for the U.S. Environmental Protection Agency, May 15, 1977.

28. Donald A. Blome and James E. Jones, Jr. *Regional Assessment of the Impact of Synthetic Fuel Production.* ORBES vol. III-J. Prepared for the U.S. Environmental Protection Agency, May 15, 1977.

29. C. Bliss et al. *Accidents and Unscheduled Events Associated with Non-Nuclear Energy Resources and Technology.* EPA-600/7-77-016. U.S. Environmental Protection Agency, Washington, D.C., February 1977.

30. "1976 Summary of Coal Mine Injuries and Worktime." *Safety Reviews.* Mining Enforcement and Safety Administration, February 1977.

31. *Keystone Coal Industry Manual,* McGraw-Hill, New York, 1977.

32. *Health, Environmental Effects, and Control Technology of Energy Use.* EPA 600/7-76-002. U.S. Environmental Protection Agency, Washington, D.C., 1976.

33. *Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants.* U.S. Nuclear Regulatory Commission. WASH-1400. Washington, D.C., 1975.

34. U.S. Atomic Energy Commission. WASH-740. Washington, D.C., 1957.

35. William D. Rowe. *Reactor Safety Study (WASH 1400): A Review of the Final Report*. U.S. Environmental Protection Agency, Washington, D.C., June 1976.

36. H. W. Lewis et al. "Report to the American Physical Society by the Study Group on Light-Water Reactor Safety." *Reviews of Modern Physics*, vol. 47 (1975):S1-S124.

37. *The Risks of Nuclear Power Reactors: A Review of the NRC Reactor Safety Study*. Union of Concerned Scientists, Cambridge, Massachusetts, November 1977.

38. C. L. Comar and L. A. Sagan. "Health Effects of Energy Production and Conversion." In: *Annual Review of Energy*, vol. I, Jack M. Hollander, ed. Annual Reviews, Inc., Palo Alto, California, 1976.

39. Richard A. Tybout. *A Benefit-Cost Analysis of Power in the ORBES Region*. ORBES vol. III-B. Prepared for the U.S. Environmental Protection Agency, May 15, 1977.

40. Sue Johnson and Esther Weil. *Social Aspects of Power Plant Siting*. ORBES vol. III-D. Prepared for the U.S. Environmental Protection Agency, May 15, 1977.

41. *Development of Baseline Data for the Ohio River Basin Energy Study*. ORBES vol. I-B. Prepared for the U.S. Environmental Protection Agency, May 15, 1977.

42. Sven B. Lundstedt, Henry L. Hunker, and Clark Leavitt. *Subjective Quality of Life in the Ohio River Basin as Related to Future Energy Development*. ORBES vol. III-C. Prepared for the U.S. Environmental Protection Agency, May 15, 1977.

43. Harold G. Cassidy. *A White Paper, V. The Marble Hill Hearings: A Tragic Farce in Eight Acts*. Prepared for Save the Valley Inc., June 15, 1977.

APPENDIX A

STUDY ORGANIZATION

Chapter 2 of this report touches upon organizational arrangements devised to carry out the initial year of the Ohio River Basin Energy Study. A more detailed description of the study organization and of evolving relationships between the federal granting agency--the Environmental Protection Agency--and the participating universities is provided in this appendix. It is hoped that this discussion will be of interest both to students of research-and-development management and to citizens seeking to understand how certain government decisions are made.

As noted in Chapter 2, the first official step toward formalizing the ORBES project was taken in late July 1975, when the U.S. Senate Appropriations Committee directed EPA "to conduct. . . an assessment of the. . . impacts of the proposed concentration of power plants in the lower Ohio River Basin." During the next few months, EPA considered a variety of organizational approaches to carry out this mandate from Congress. By winter 1975-1976 officials of EPA's Office of Research and Development had decided to utilize university personnel in the undertaking. In spring 1976, EPA invited researchers from a selected group of midwestern universities to prepare proposals for internal and external review to carry out various tasks outlined in a work plan provided by the agency.

On May 19, 1976, the authors of this report submitted a proposal entitled "Experimental Management Plan for an Impact Assessment of Energy Conversion Facilities in the Ohio River Basin, Phase I." In that proposal, it was asserted that management arrangements for interdisciplinary research projects are often inadequate:

> This inadequacy is intensified when attempts are made to implement research efforts which involve investigators from more than one university campus. When such endeavors include researchers from two or more states difficulties are magnified. . . .The investigators preparing this proposal believe that present evidence is inconclusive as to the most promising research management forms for interstate-interinstitutional research projects involving energy and the environment. It is their belief, therefore, that many experiments must be undertaken to test the efficacy of a host of managerial arrangements.

The proposal further argued that the literature of interstate energy and environmental research (meager as it is) demonstrates well that "unprecedented social, economic, and 'political' elements present constraints likely never faced before by university researchers. The character of this. . . study is so complex that any ultimate management arrangement by necessity must be an experiment in the sense that its results can in no way be predicted at this time." It was emphasized that it would be unrealistic to ignore inevitable political considerations involving long-standing sensitivities between and among states, universities, and the federal government. Because of these sensitivities, the authors felt the need to attach the condition that independent access to members of the U.S. Congress, as well as governors and other state officials, would not be denied them. (As noted in the preface, EPA did indeed accord the authors total independence during Phase I and encouraged them to seek counsel from public officials at all levels.)

The proposal outlined general administrative functions for the ORBES project and described how coordination and guidance would be achieved among the four task groups defined in the EPA work plan. This was to be accomplished chiefly through a project office to be established within the University of Illinois, with that institution as fiscal agent. The proposal also stated that the authors would be responsible for preparing an integrated summary report at the close of Phase I.

In early August 1976, EPA announced that funding for this management plan, in the amount of $113,995, was among a series of grants totaling $720,579 awarded to researchers at universities located in the states of Illinois, Indiana, Kentucky, and Ohio to begin ORBES Phase I. Selected to undertake the preliminary technology assessment and special study aspects of the initial year were researchers from the following campuses: Indiana University, Bloomington, Indiana; the University of Kentucky, Lexington, Kentucky; the University of Louisville, Louisville, Kentucky; The Ohio State University, Columbus, Ohio; Purdue University, West Lafayette, Indiana; and both the Chicago Circle and Urbana-Champaign campuses of the University of Illinois.

The combined grants provided funding to more than 100 researchers (including student assistants) on the seven campuses. Four basic research tasks were to be performed by various combinations of university faculty and staff. At the center of the first year's activity were three preliminary assessments, to be carried out independently by three university teams.

The overall relationships among these various responsibilities and units are depicted in Figure A-1. A project officer from EPA's Office of Energy, Minerals, and Industry, Washington, D.C., became responsible for general oversight of the ORBES project and continued in that role throughout the year. Two regional EPA offices--Region IV, with offices in Atlanta, Georgia, and Region V, with offices in Chicago, Illinois--have jurisdiction over portions of the study area. A representative from each of these offices was appointed to join the project officer and the authors of this report on the Project Management Team.

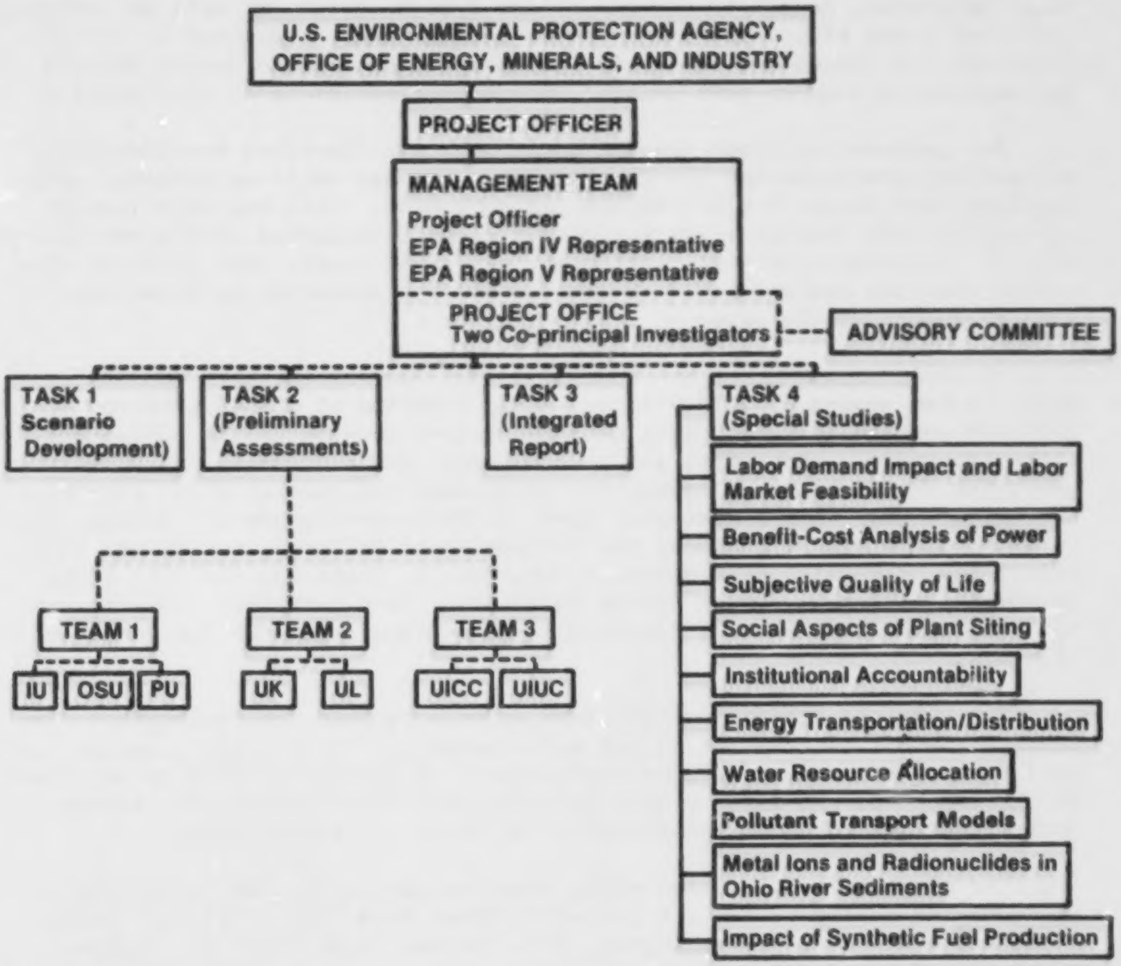
U.S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF ENERGY, MINERALS, AND INDUSTRY
PROJECT OFFICER
MANAGEMENT TEAM
Project Officer
EPA Region IV Representative
EPA Region V Representative
PROJECT OFFICE
Two Co-principal Investigators
ADVISORY COMMITTEE
TASK 1 Scenario Development)
TASK 2 (Preliminary Assessments)
TASK 3 (Integrated Report)
TASK 4 (Special Studies)
Labor Demand Impact and Labor Market Feasibility
Benefit-Cost Analysis of Power
Subjective Quality of Life
Social Aspects of Plant Siting
Institutional Accountability
Energy Transportation/Distribution
Water Resource Allocation
Pollutant Transport Models
Metal Ions and Radionuclides in Ohio River Sediments
Impact of Synthetic Fuel Production
TEAM 1
TEAM 2
TEAM 3
IU
OSU
PU
UK
UL
UICC
UIUC

FIGURE A-1. OHIO RIVER BASIN ENERGY STUDY ORGANIZATION, PHASE I

Since much of the impetus for the ORBES project came from the concerns of citizens in the study area, from its earliest planning EPA envisaged active participation of representatives of major public and private sectors in the region. In September 1975 in Louisville, Kentucky, an Interim Steering Committee was convened to provide counsel to the researchers in the early ORBES planning. Within a few weeks members of this interim committee and other appointees were phased into a permanent ORBES Advisory Committee. The Advisory Committee (listed in Appendix D) provided counsel and suggestions throughout the first year. Among their contributions were critiques of the three preliminary assessment reports and of this integrated summary report.

As noted in the foreword, EPA has decided to support the initial year of Phase II of ORBES; on November 1, 1977, the agency announced that a series of grants had been awarded to an expanded group of universities. In addition to the six institutions named above, grants were received by researchers at the University of Pittsburgh and West Virginia University. Awards to these two institutions reflected EPA's decision to include virtually all of West Virginia and southwestern Pennsylvania in the ORBES Phase II study region.

The complexity of such regional assessments is illustrated by the fact that Pennsylvania and West Virginia are located in still another EPA region (Region III, with offices in Philadelphia). Under a new grant, the authors will continue as co-directors for the university management team. In a departure from the Phase I format, however, a single core team of thirteen researchers from the eight universities will carry out the impact assessment of Phase II. A group of support studies also will be funded.

APPENDIX B

ORBES PHASE I REPORTS

VOLUME	
I-A	*ORBES Phase I: Interim Findings*, by James J. Stukel and Boyd R. Keenan (identical to the present report)
I-B	*Development of Baseline Data for the Ohio River Basin Energy Study*
II	*Preliminary Technology Assessment Reports*
II-A	Indiana University, The Ohio State University, and Purdue University
II-B	University of Kentucky and University of Louisville
II-C	University of Illinois at Chicago Circle and at Urbana-Champaign
III	*Special Study Reports*
III-A	*Labor Demand Impact and Labor Market Feasibility of Energy Conversion Facilities in the Ohio River Basin*, by Robert C. Dauffenbach and Thomas P. Milke (University of Illinois at Urbana-Champaign)
III-B	*A Benefit-Cost Analysis of Power in the ORBES Region*, by Richard A. Tybout (The Ohio State University)
III-C	*Subjective Quality of Life in the Ohio River Basin as Related to Future Energy Development*, by Sven B. Lundstedt, Henry L. Hunker, and Clark Leavitt (The Ohio State University)
III-D	*Social Aspects of Power Plant Siting*, by Sue Johnson and Esther Weil (University of Kentucky)
III-E	*Legal Analysis of Institutional Accountability for the Ohio River Basin*, by Nicholas L. White and John F. Fitzgerald (Indiana University)
III-F	*Energy Transportation/Distribution in the Ohio River Basin*, by Michael Rieber (University of Illinois at Urbana-Champaign)

III-G *Issues Related to Water Allocation in the Lower Ohio River Basin,* by E. Downey Brill, Jr., Glenn E. Stout, Robert W. Fuessle, Randolph M. Lyon, and Keith E. Wojnarowski (University of Illinois at Urbana-Champaign)

III-H *Pollutant Transport Models for the ORBES Region,* by R. E. Bailey, R. G. Barile, D. D. Gray, R. B. Jacko, P. O'Leary, R. A. Rao, and J. E. Reinhardt (Purdue University)

III-I *Radionuclide and Metal Ion Content of Late Summer Ohio River Sediments: McAlpine Pool 1976,* by Clara A. Leuthart and Hugh T. Spencer (University of Louisville)

III-J *Regional Assessment of the Impact of Synthetic Fuel Production,* by Donald A. Blome and James E. Jones, Jr. (University of Kentucky)

IV *Independent Comments*

APPENDIX C

ORBES PHASE I PERSONNEL

ORBES PERSONNEL

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See the listing in Appendix B for the authors of the ten special study reports (Volumes III-A through III-J).

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APPENDIX D

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APPENDIX E

STUDY ORIGINS

A series of decisions made at the national level nearly 30 years ago predetermined that the lower Ohio River Basin would be at the center of the country's fuel conflicts in the 1970s and 1980s. Indirectly, these same events led to the concerns of residents along the 100-mile reach of the Ohio River stretching from Louisville, Kentucky, northward and eastward to and beyond Cincinnati, Ohio.

In November 1950, the U.S. Atomic Energy Commission (AEC) approved construction of the nation's second gaseous diffusion uranium enrichment plant near Paducah, Kentucky, located on the Ohio River about 935 river miles downstream from Pittsburgh. During World War II and the immediate postwar period, all of the nation's uranium was enriched at Oak Ridge, Tennessee, site of the world's first gaseous diffusion plant, built as part of the Manhattan Project. Located in northeastern Tennessee, Oak Ridge is just outside the Ohio River Basin.

By 1952, the AEC had begun plans for the nation's third gaseous diffusion plant, to be located near Portsmouth, Ohio (about Mile 340), where the Scioto River flows south into the Ohio. Electric power demands for the Portsmouth uranium enrichment facility were so great that the AEC contracted with a consortium of investor-owned public utilities to provide energy from what would become for a time the world's two largest coal-fired power plants. Partially for national defense reasons, it was decided that the plants should be sited a considerable distance from each other and from the uranium enrichment plant itself.

The consortium--the Ohio Valley Electric Corporation (OVEC)--selected Ohio River sites 220 river miles west of Portsmouth at Madison, Indiana, and 80 river miles east at Cheshire, Ohio. In early 1955, the first units of both facilities--the Clifty Creek plant near Madison and the Kyger Creek plant at Cheshire--went "on-line." Transmission lines charged at 330,000 volts (the hightest voltage level in the country at the time) carried electric power to the uranium plant at Portsmouth. Three 680-foot stacks at the Clifty Creek plant were then the tallest in the world. From 1955 to 1974 they remained as the focus of Madison residents' resentment at the plant's presence.

During this 25-year period, hostility increased between a portion of the Madison citizenry and consortium companies operating at Clifty Creek.[1] Reports from OVEC reflected pride in its achievements: "Air pollution was carefully studied. The high-stack concept--releasing stack gases at high velocity far above the level where people breathe--is now a standard approach to air quality control. It was a world-first at Clifty and Kyger" ("Twins on the Ohio: This is OVEC-IKEC," brochure, n.d.). Under present air quality regulations, high stacks are not an adequate abatement mechanism.

A growing number of residents in Madison and the surrounding area took issue with OVEC claims of concern for the environment during the early 1970s. Ironically, OVEC could probably not have selected a community site with more overall pride in aesthetics and total environment. A town of 13,000 nestled below the bluffs along the Ohio River, Madison is characterized as a living museum of nineteenth-century architecture, with scores of buildings recognized as national historic treasures. The local chamber of commerce calls it "the Williamsburg of the Midwest."

The 1973-1974 Arab oil embargo stimulated national policy discussions on coal produced in the Ohio River Basin and possible new power plants in the region. In Madison, reports began circulating, supported by statements from area public utilities, that 30- to 40-mile stretches of the river--both upstream and downstream from Madison--were being considered as prime sites for additional coal-fired power plants. In response, a group of Indiana and Kentucky residents around the Madison area incorporated under the name Save the Valley (STV). The organization's early public reports indicate chief concerns over the concentration of coal-burning plants on both sides of the river.

The Clifty Creek plant and the historic character of Madison were major factors placing STV in a uniquely critical role in power plant siting debates in the Ohio River Basin. On September 20, 1974, members of STV met in the nation's capital with federal officials, organized by U.S. Senator Birch Bayh of Indiana. In an apparent reference to the Clifty Creek plant, a spokesman for the group asserted: "We've been living with broken promises for twenty years. That's why we're worried about the future" (*Louisville Courier-Journal,* September 20, 1974).

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[1] Members of the consortium are: Appalachian Power Company, Cincinnati Gas and Electric Company, Columbus & Southern Ohio Electric Company, Dayton Power & Light Company, Indiana & Michigan Electric Company, Kentucky Utilities Company, Louisville Gas & Electric Company, Monongahela Power Company, Ohio Edison Company, Ohio Power Company, Pennsylvania Power Company, Potomac Edison Company, and West Penn Power Company. Appalachian, Indiana & Michigan, and Ohio Power are subsidiaries of American Electric Power, Inc. Monongahela, Potomac Edison, and West Penn Power are subsidiaries of the Allegheny Power System, Inc. Pennsylvania Power is a subsidiary of Ohio Edison. OVEC operates the Clifty Creek plant through its own subsidiary, known as the Indiana-Kentucky Electric Corporation (IKEC).

Senator Bayh urged STV and federal officials to "get all the facts spread on the table" so that a study could be arranged. A year later, Senator Bayh declared that "these concerned individuals had tried to track down information about several proposed power plants along the river. But every time they contacted an Indiana, Kentucky, or federal agency the buck was passed. . . . They were getting nowhere and they were frustrated." (*News from Birch Bayh,* July 22, 1975).

"The consensus was that an in-depth study of the development of power in this region would be the best way to address these concerns," Bayh said. He continued: "This study will allow everyone involved in the decision-making process about power development to share the same information, to speak the same language. It will go a long way toward putting the individual concerned citizen on an equal footing with the state and federal agencies and the power companies. We need adequate power supplies. But we need to protect ourselves and our environment, and that can't happen unless the citizens of our communities play an active, informed role in the decision-making process about energy development."

Senator Bayh is a member of the Senate Appropriations Committee and its subcommittee with authority to review EPA appropriations. Reportedly at Bayh's request, the committee's report on EPA's fiscal year 1976 funding formally directed the agency to perform a specific study, the project that would later be named the Ohio River Basin Energy Study (ORBES).

APPENDIX F

SCENARIO ASSUMPTIONS, SITING CONSTRAINTS, AND SITING CONFIGURATIONS

In developing the ORBES scenarios a number of assumptions were made. Some of these assumptions apply to both the high-energy-growth option (Bureau of Mines) and the low-energy-growth option (Ford Technical Fix). These assumptions were as follows (41):

1. Of all the electrical energy generated in one year in the United States, 11.9 percent is generated in the ORBES region. It is assumed that this percentage will remain constant through the year 2000.

2. It is assumed that electrical energy demand in the United States is a direct indication of energy demand in the ORBES region, but the converse is not necessarily true.

3. It is assumed that electrical energy production in the ORBES region roughly equals consumption. That is, the net exports (from the four ORBES states, not the region) are zero, and it is assumed that they will remain zero through the year 2000.

4. It is assumed that in the next 25 years the major sources of electrical energy in the ORBES region will be coal and uranium. (Geothermal power and solar energy will be taken into account in Phase II of the project.)

5. It is assumed that the ORBES region will supply 5.5 percent of its own needs for natural gas.

6. The driving force behind the scenarios is the economic situation in the United States and its effects on national energy demand. Any major occurence not now accounted for could have a serious disruptive effect on these forecasts, for example, a major war, another Arab embargo, or a new extensive governmental policy concerning energy development or environmental controls.

7. It is assumed that sufficient uranium is available to meet demands for projected nuclear plants. The supply of coal is also sufficient to meet the demand. Water can be found in quantities abundant enough to meet the needs of new plants.

8. It is assumed that existing governmental regulations will remain in effect through the year 2000.

9. It is assumed that labor demand can be met for both skilled and unskilled positions related to the building and operation of new power plants.

10. It is assumed that sufficient capital will be available to finance the building of new facilities.

11. It is assumed that the plants projected in the scenarios will meet all existing pollution control standards.

12. The five major sources of electrical energy are coal, petroleum, natural gas, uranium, and (perhaps) hydropower.

13. It is assumed that technology and governmental policies will determine the supply of resources available for development.

14. By agreement, the capacity per unit will be 1000 MWe for incremental additions to existing power plants, unless otherwise stated.

15. It is assumed that all projected plants will be in areas meeting minimum size requirements.

16. It is assumed that mineral rights can be acquired when necessary.

17. It is assumed that the location of projected plants will be away from population centers and major metropolitan areas.

18. It is assumed that the availability and accessibility of transmission lines present no problem in regard to plant siting.

19. It is assumed that the chance of concentrated power parks being constructed in the ORBES region in the next 25 years is highly remote.

20. It is assumed that the number of additional power plants in the ORBES region through 1985 is as listed in Reference 41, Section lg/h.

21. It is assumed that there will be at least one nuclear plant built in Kentucky by the year 2000.

22. It is assumed that all new power plants will meet the "best available control technology" environmental standards and will also use the best available construction technology.

An additional series of assumptions were made for each of the basic energy-growth options. These were the assumptions made in the Bureau of Mines (2) and Ford Foundation (3) studies; they are implicit in the ORBES scenarios. The following are some of the major assumptions made for the BOM study (for details, see Reference 2):

1. In the year 2000 the gross national product (GNP) in the United States will be $2981 billion (1971 dollars).

2. The national population will be 264 million in the year 2000.

3. Annual energy consumption will increase at an average rate of 3.1 percent between the early 1970s and the year 2000--from 73 quadrillion Btu's in 1974 to 163 quadrillion Btu's in 2000.

4. The regulation of strip mining will not be overly restrictive.

5. The leasing of federal offshore areas will continue at an accelerated pace.

6. The federal government will lease western coal lands, oil shale lands, and known areas of geothermal energy.

7. The government will continue to support research and development.

8. The Federal Power Commission will relax regulation of wellhead prices.

9. Domestic crude oil prices will be decontrolled.

10. A policy seeking to rationalize the world petroleum market will be established.

11. Price effects will not be incorporated.

12. Commercially feasible techniques for coal gasification and liquefaction will be developed.

13. Economically viable techniques for the control of sulfur oxide emissions from power and industrial plants will be developed.

14. The breeder reactor will be introduced.

15. The role of solar energy will not be taken into account.

16. Energy conservation will not be taken into account.

17. The slow trend toward a service-oriented economy will continue.

Some of the basic assumptions made for the Ford Technical Fix are listed below (for details, see Reference 3):

1. Long-term energy prices and government policies will encourage greater efficiency in energy consumption.

2. Annual energy consumption will increase at an average rate of 1.9 percent between the early 1970s and the year 2000--from 73 quadrillion Btu's in 1975 to 115 quadrillion Btu's in 2000.

3. The nation will adopt specific energy-saving technologies, for example: (a) direct energy savings resulting from the application of energy-conservation technologies at the point of energy use (such as increased use of thermal insulation and heat pumps, improved automotive fuel economy, and total energy systems); and (b) indirect energy savings in the energy

processing sector (such as power plants, petroleum refineries, and uranium enrichment plants).

4. In the year 2000 the GNP in the United States will be $3219 billion (1971 dollars).
5. The national population will be 236 million in 1985 and 265 million in 2000.

Location of the hypothetical energy conversion facilities under the scenarios was at the county level. The following general constraints were taken into account:

1. Transportation accessibility
2. Site development
3. Water supply and hydrology
4. Climatology
5. Population distribution and density in the plant vicinity
6. Seismic design requirements
7. Accessibility by labor force, heavy equipment, and plant components
8. Transmission line corridors
9. Fuel supply
10. Terrestrial ecological sensitivity
11. Aquatic ecological sensitivity (waste heat and chemicals)
12. Demographic patterns

Specific constraints on selecting sites for coal facilities included:

1. A facility cannot be sited within a highly polluted area.
2. Primary standards for sulfur dioxide, nitric oxide, and particulates must be met.

(See reference 41.)

See Figure F-1 for a map showing electrical generation units in the region as of December 31, 1975. The remaining maps depict hypothetical facilities projected under each of the scenarios in addition to existing facilities: the BOM 80 percent coal/20 percent nuclear (Figure F-2); the BOM 50 percent coal/50 percent nuclear (Figure F-3); the FTF 100 percent coal (Figure F-4); and the FTF 100 percent nuclear (Figure F-5).

FIGURE F-1. ELECTRICAL GENERATING UNITS, ORBES REGION, DECEMBER 31, 1975

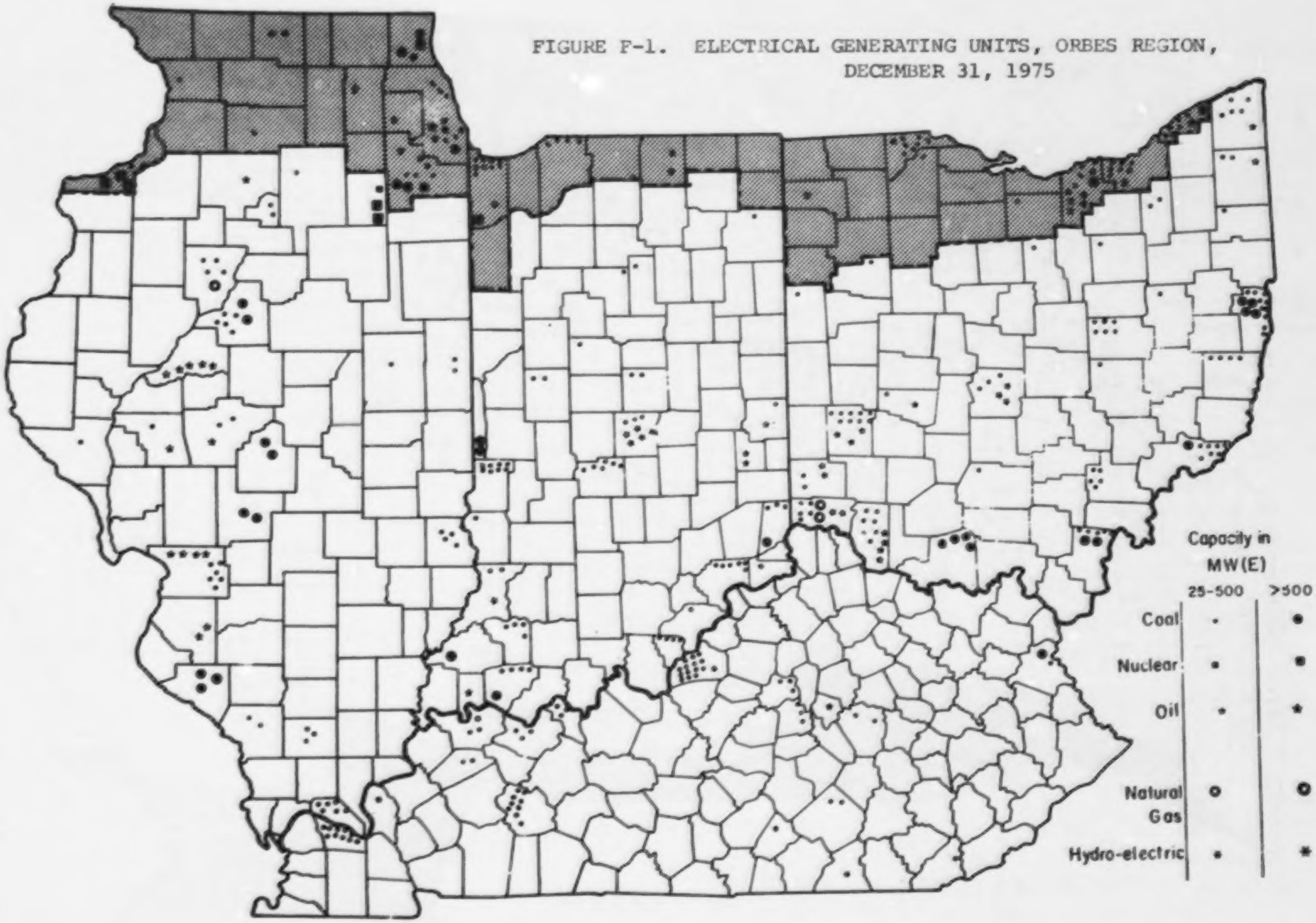

Capacity in MW(E)
25-500
>500
Coal
Nuclear
Oil
Natural Gas
Hydro-electric

FIGURE F-2. ELECTRICAL GENERATING UNITS, ORBES REGION, BOM 80 PERCENT COAL/20 PERCENT NUCLEAR SCENARIO, 2000

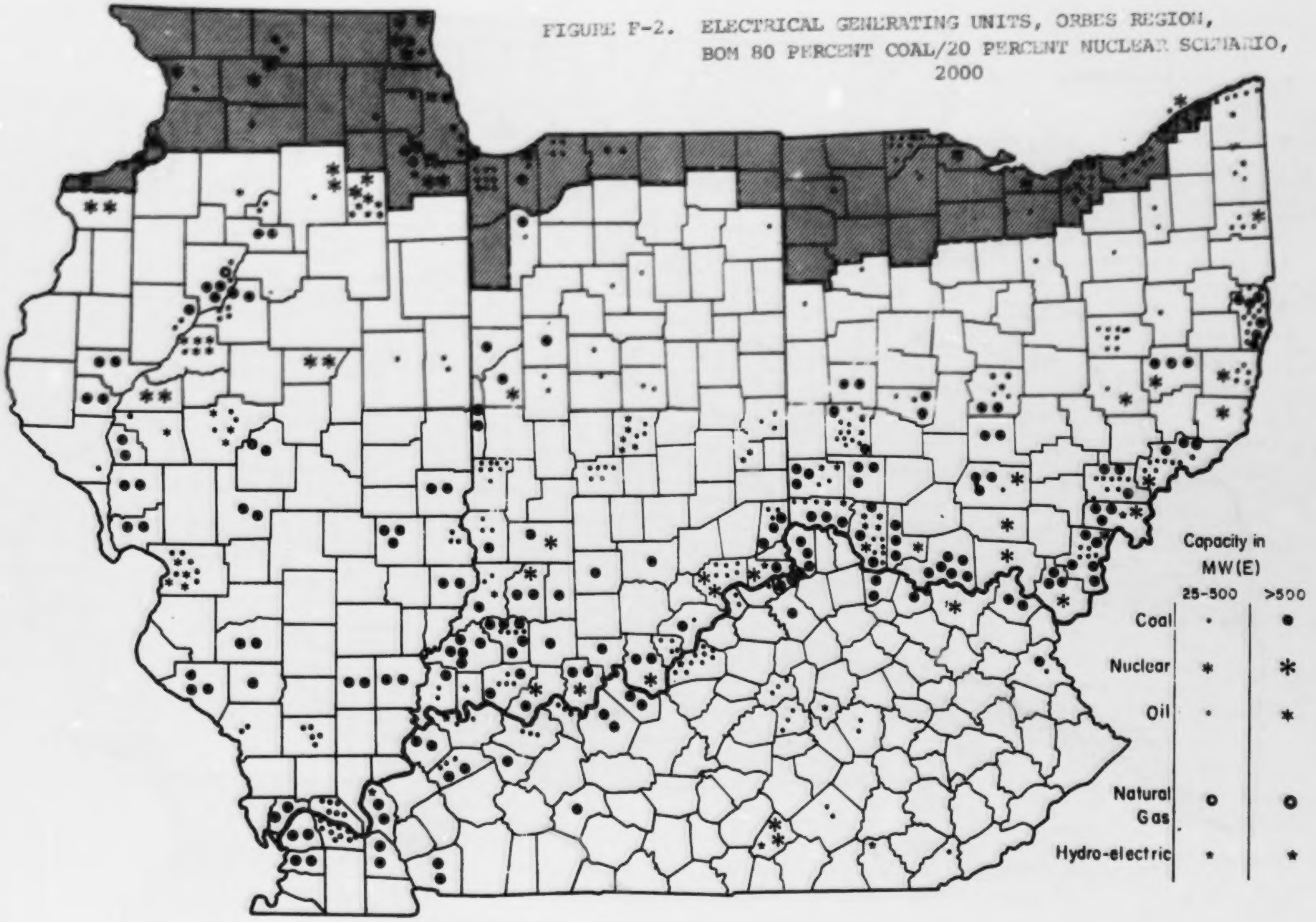

Capacity in MW(E)
25-500
>500
Coal
Nuclear
Oil
Natural Gas
Hydro-electric

FIGURE F-3. ELECTRICAL GENERATING UNITS, ORBES REGION, BOM 50 PERCENT COAL/50 PERCENT NUCLEAR SCENARIO, 2000

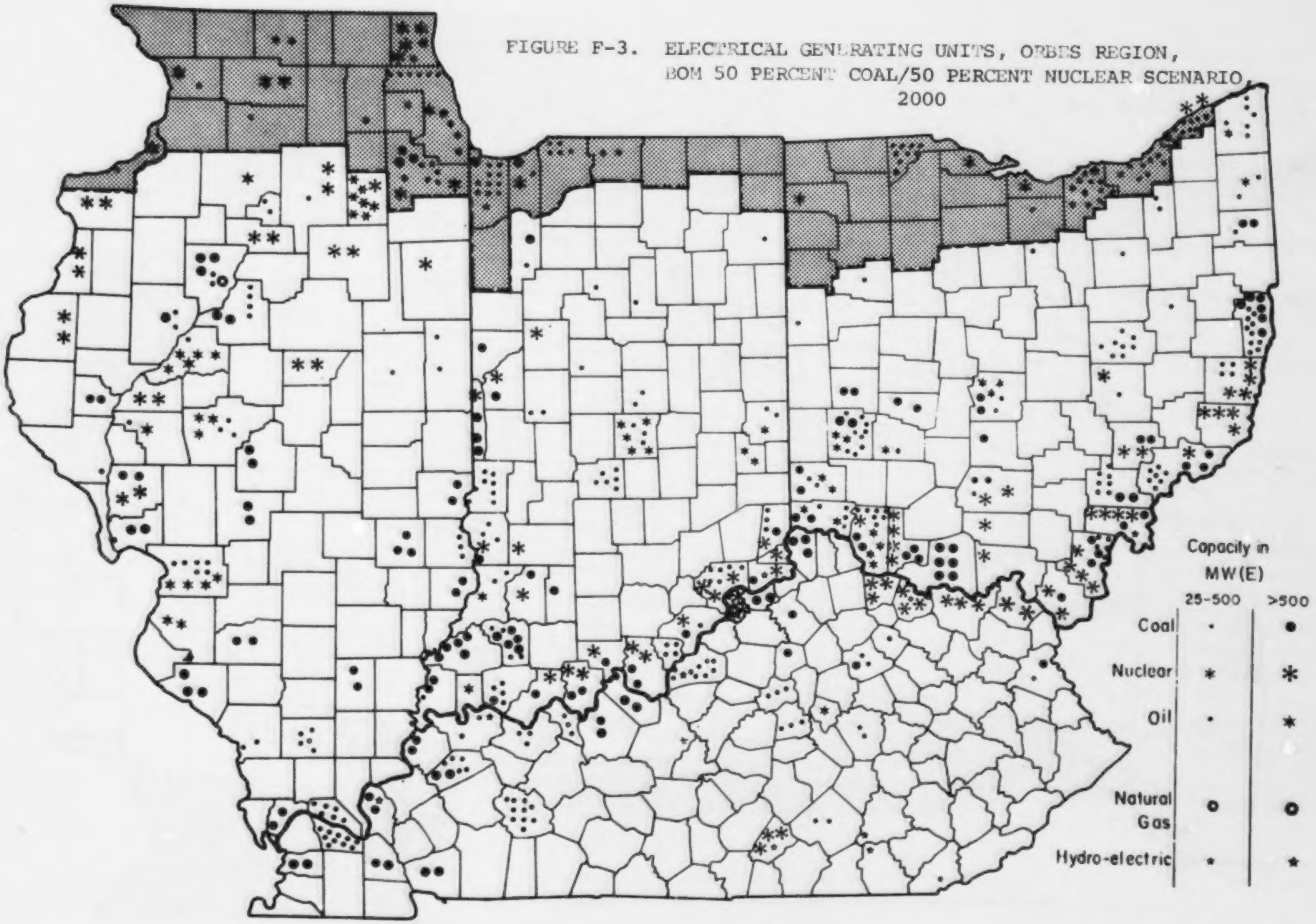

Capacity in MW(E)
25-500
>500
Coal
Nuclear
Oil
Natural Gas
Hydro-electric

FIGURE F-4. ELECTRICAL GENERATING UNITS, ORBES REGION, FTF 100 PERCENT COAL SCENARIO, 2000

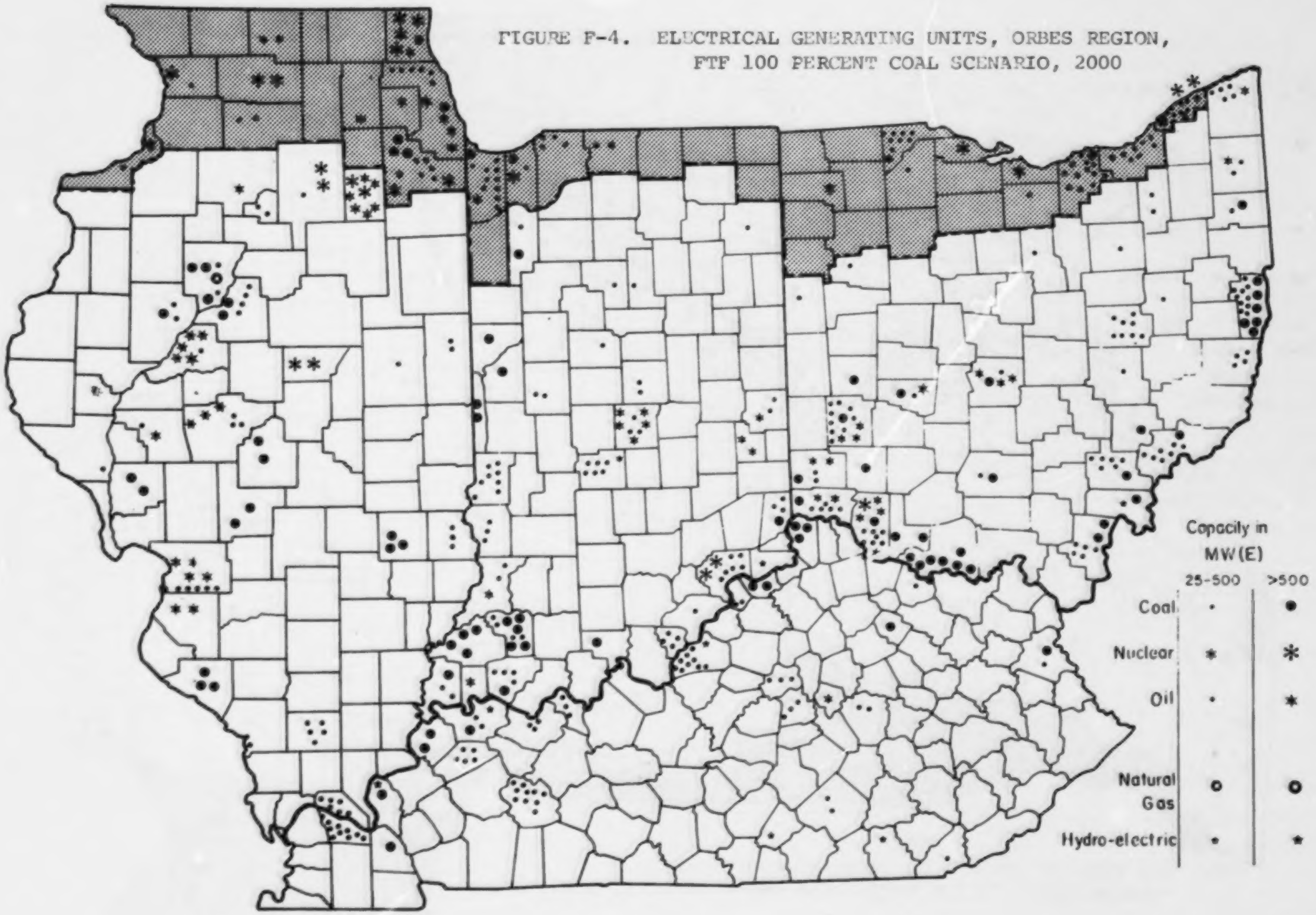
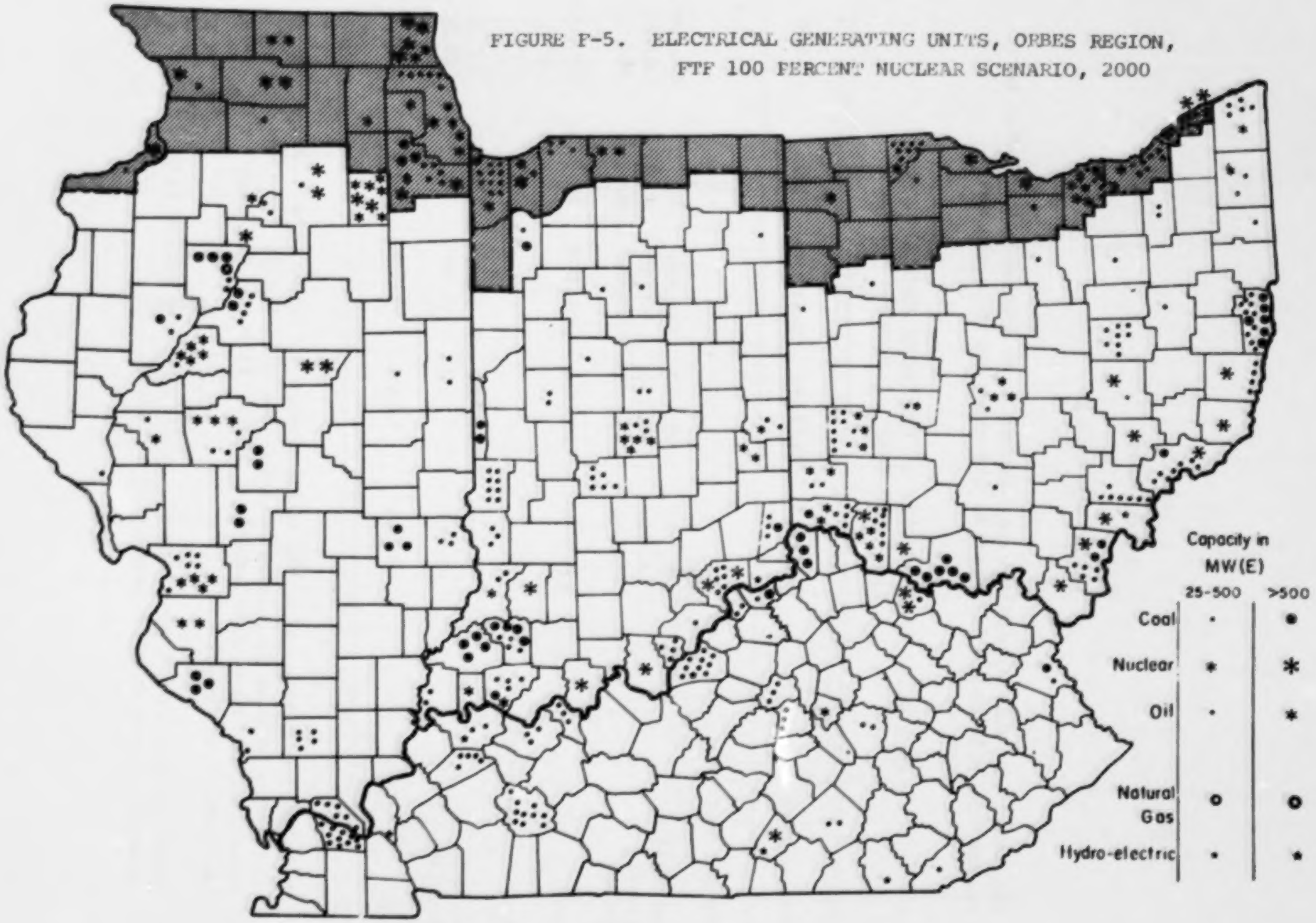

Capacity in MW(E)
25-500
>500
Coal
Nuclear
Oil
Natural Gas
Hydro-electric

FIGURE F-5. ELECTRICAL GENERATING UNITS, ORBES REGION, FTF 100 PERCENT NUCLEAR SCENARIO, 2000


Capacity in MW(E)
25-500
>500
Coal
Nuclear
Oil
Natural Gas
Hydro-electric

APPENDIX G

WATER USE DATA

The tables in this appendix were adapted from Reference 9. Refer to that volume for additional information and notes on data sources.

TABLE G-1. WATER SUPPLY IN THE ORBES REGION
(in cubic feet per second)

Water supply	Illinois	Indiana	Kentucky	Ohio	Total
Average conditions					
Rainfall	140,000	95,000	140,000	98,000	471,000
Runoff	34,000	28,000	50,000	30,000	140,000
Inflow[*]	160,000	0[*]	80,000	50,000	290,000
Total[†]	200,000	28,000	130,000	79,000	440,000
Low-flow conditions					
Runoff	1,500	1,700	1,400	1,800	6,400
Inflow[*]	43,000	0[*]	31,000	4,500	78,000
Total[†]	45,000	1,700	32,000	6,300	85,000

[*] Only inflow from outside the ORBES region is given here. Thus, the inflow to Indiana is listed as zero; the Ohio River, for example, is accounted for as a combination of runoff from the different states and inflow to Ohio.

[†] Total equals inflow plus runoff. Totals do not necessarily equal sums of column entries because of rounding.

TABLE G-2. WATER USE IN 1970, ORBES STATES AND STATE PORTIONS (in cubic feet per second)

	Illinois	Indiana	Kentucky	Ohio	Total
Water withdrawal					
Municipal	430.0	720.0	480.0	1,400.0	3,000.0
Industrial	1,500.0	400.0	450.0	3,300.0	5,600.0
Power	18,000.0	6,500.0	5,900.0	21,000.0	51,000.0
Total	19,000.0	7,600.0	6,900.0	26,000.0	60,000.0
*Water consumption**					
Municipal	86.0	140.0	96.0	270.0	600.0
Industrial	87.0	24.0	27.0	200.0	330.0
Power	7.7	7.7	33.0	22.0	70.4
Total	180.0	180.0	160.0	490.0	1,000.0

*Estimated at 20 percent of withdrawals for municipalities and 6 percent for industries.

NOTE: Municipal and industrial estimates are for the areas of each state within the ORBES region. Power estimates are for the entire state.

TABLE G-3. PROJECTED WATER USE, ORBES REGION, 1985
(in cubic feet per second)

	Illinois	Indiana	Kentucky	Ohio	Total
Water withdrawal					
Municipal	470	790	560	1,500	3,400
Industrial	2,500	730	770	3,700	7,700
Power	720	560	510	1,000	2,800
Total	3,700	2,100	1,800	6,300	14,000
Water consumption					
Municipal	95	160	110	310	670
Industrial	150	44	46	220	460
Power	480	370	340	670	1,900
Total	720	570	500	1,200	3,000

TABLE G-4. PROJECTED WATER USE, ORBES REGION, BOM 80/20 SCENARIO, 2000
(in cubic feet per second)

	Illinois	Indiana	Kentucky	Ohio	Total
Water withdrawal					
Municipal	540	910	660	1,700	3,800
Industrial	3,800	1,200	1,200	6,000	12,000
Power	1,600	1,500	1,400	2,600	7,000
Total	5,900	3,600	3,000	10,000	23,000
Water consumption					
Municipal	110	180	130	340	760
Industrial	230	71	71	360	730
Power	1,000	1,000	930	1,700	4,700
Total	1,400	1,200	1,100	2,400	6,200

TABLE G-5. PROJECTED WATER USE, ORBES REGION, BOM 50/50 SCENARIO, 2000
(in cubic feet per second)

	Illinois	Indiana	Kentucky	Ohio	Total
Water withdrawal					
Power	1,700	1,600	1,500	2,800	7,600
Total municipal, industrial, and power withdrawals	6,000	3,700	3,400	10,000	24,000
Water consumption					
Power	1,100	1,100	1,000	1,900	5,100
Total municipal, industrial, and power consumption	1,500	1,300	1,200	2,600	6,600

TABLE G-6. PROJECTED WATER USE, ORBES REGION, FTF 100 PERCENT COAL SCENARIO, 2000
(in cubic feet per second)

	Illinois	Indiana	Kentucky	Ohio	Total
Water withdrawal					
Power	750	620	580	1,200	3,200
Total municipal, industrial, and power withdrawals	5,100	2,700	2,400	8,900	19,000
Water consumption					
Power	500	420	390	810	2,100
Total, municipal, industrial, and power consumption	840	670	590	1,500	3,600

TABLE G-7. PROJECTED WATER USE, ORBES REGION, FTF 100 PERCENT NUCLEAR SCENARIO, 2000
(in cubic feet per second)

	Illinois	Indiana	Kentucky	Ohio	Total
Water withdrawal					
Power	760	660	620	1,300	3,400
Total municipal, industrial, and power withdrawals	5,100	2,800	2,500	9,000	19,000
Water consumption					
Power	500	440	410	880	2,200
Total municipal, industrial, and power consumption	840	690	610	1,600	3,700

TABLE G-8. WATER CONSUMPTION FOR IRRIGATION COMPARED TO OTHER USES, ORBES REGION, 2000

	Irrigation consumption (cfs)			*Scenario consumption (cfs)*	
	low	moderate	high	BOM 50/50*	FTF 100 percent coal*
Illinois	170 (33)	530 (100)	1100 (200)	1500	840
Indiana	110 (20)	530 (100)	1100 (200)	1300	670
Kentucky	110 (20)	210 (40)	320 (60)	1200	590
Ohio	110 (20)	800 (150)	1300 (250)	2600	1500
Total	500 (93)	2100 (390)	3800 (710)	6600	3600

*Estimates are for municipal, industrial and power uses.

NOTE: Irrigated acreages appear in parentheses (thousands of acres).

TABLE G-9. RIVER BASIN CONSUMPTION RATIOS, ORBES REGION, BOM 50/50 SCENARIO

River basin	Number of plant units	Minimum ratio	Maximum ratio	Average ratio for all reaches	Relative impact
Muskingum, OH	5	.12	.20	.16	moderate
Big Sandy, KY	0	.02	.02	.02	light
Scioto, OH	8	.43	1.45	.83	heavy
Licking, KY	0	.18	.18	.18	moderate
Great Miami, OH	8	.41	.96	.58	heavy
Little Miami, OH	0	0	0	0	light
Kentucky, KY	2	.03	.37	.20	moderate
Salt, KY	0	*	*	*	heavy
Green, KY	2	.008	.14	.11	moderate
Wabash, IN	18	.01	.23	.14	moderate
Cumberland, KY	5	.02	.26	.10	moderate
Ohio River	135[†]	.006	.14	.10	moderate rate
Kaskaskia, IL	2	.65	.65	.65	heavy
Big Muddy, IL	0	.33	.33	.33	heavy
Mississippi River	24[†]	.007	.05	.026	light

[*] No ratios calculated since the 7-day 10-year flow is zero.

[†] All power plants in the ORBES region were taken into account in calculating the consumption ratios for the Ohio River. Only plants in the ORBES portion of Illinois were considered for the Mississippi River.

TABLE G-10. RIVER BASIN CONSUMPTION RATIOS, ORBES REGION, FTF 100 PERCENT COAL SCENARIO

River basin	Number of plant units	Minimum ratio	Maximum ratio	Average ratio for all reaches	Relative impact
Muskingum, OH	1	.04	.07	.055	moderate
Big Sandy, KY	0	.02	.02	.02	light
Scioto, OH	2	.13	.64	.33	heavy
Licking, KY	0	.18	.18	.18	moderate
Great Miami, OH	4	.15	.30	.19	moderate
Little Miami, OH	1	.63	.63	.63	heavy
Kentucky, KY	0	.02	.03	.03	light
Salt, KY	0	*	*	*	heavy
Green, KY	0	.008	.00	.008	light
Wabash, IN	3	.01	.13	.07	moderate
Saline, IL	0	∿0	∿0	∿0	light
Cumberland, KY	0	.01	.01	.01	light
Ohio River	22[†]	.002	.03	.02	light
Kaskaskia, IL	0	.06	.06	.06	moderate
Big Muddy, IL	0	.33	.33	.33	heavy
Illinois, IL	2	.01	.06	.03	light
Mississippi River	2[†]	0	.01	.005	light

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[*] No ratios calculated since the 7-day 10-year flow is zero.

[†] All power plants in the ORBES region were taken into account in calculating the consumption ratios for the Ohio River. Only plants in the ORBES portion of Illinois were considered for the Mississippi River.

APPENDIX H

CAPITAL INVESTMENT DATA

TABLE H-1. FINANCIAL INVESTMENT, ORBES-REGION ELECTRIC UTILITIES, ORBES SCENARIOS, CUMULATIVE TO 2000
(in billions of current dollars)

Cost function	BOM scenarios 50/50	BOM scenarios 80/20	FTF scenarios 100% coal	FTF scenarios 100% nuclear
Power plant construction	226.6	206.0	40.2	45.6
Pollution control	20.0	30.0	5.7	2.5
Transmission and substations	49.4	49.4	9.5	9.5
Distribution and substations	37.5	37.5	7.2	7.2
General expenses	9.4	9.4	1.8	1.8
Total	342.9	332.3	55.0	66.6
Capacity additions (MWe)	186,602		35,800	35,600

SOURCE: Reference 6.

TABLE H-2. CUMULATIVE CAPITAL INVESTMENT, COAL MINES, BY SCENARIO (in billions of current dollars)

Scenario	Cumulative investment to 2000	Present worth of 1975-2000 investment
BOM 80/20	9.7	4.8
BOM 50/50	6.7	3.1
FTF 100 percent coal	1.8	0.9
FTF 100 percent nuclear	1.4	0.6

SOURCE: Reference 6.

TABLE H-3. CUMULATIVE CAPITAL INVESTMENT, URANIUM MINES, BY SCENARIO (in billions of current dollars)

Scenario	Cumulative investment to 2000	Present worth of 1975-2000 investment
BOM 50/50	7.6	2.5
BOM 80/20	3.5	1.2
FTF 100 percent nuclear	1.6	0.5
FTF 100 percent coal	1.0	0.4

SOURCE: Reference 6.

APPENDIX I

MAJOR CONTRIBUTORS TO AIR AND WATER POLLUTION, ORBES STATE PORTIONS

The tables in this appendix, as well as Tables 7 and 8 in Chapter 5, summarize several types of information about the nature of environmental pollutant loadings projected under the Bureau of Mines and Ford Technical Fix scenarios. For each major air and water pollutant category (listed in column 1), columns 4, 5, and 6 of the tables indicate the percentage of total net discharges that would be generated by a given manufacturing or consumption activity in an ORBES state portion (Tables I-1 through I-8) or the ORBES region as a whole (Tables 7 and 8). Only activities contributing more than 3 percent of total residual output are presented in the tables; therefore, columns will not total 100 percent. Columns 6 and 8 indicate the percentage change between projected emissions in tons for each sector in the year 2000 and the base year (1972) discharge levels for the BOM and FTF scenarios, respectively. In column 9, the residual outputs in 2000 for the two scenarios are compared with each other. In that column, a positive difference indicates greater outputs under the low-energy-growth (FTF) scenarios; a negative difference, greater outputs under the high-energy-growth (BOM) scenarios. The tables were constructed using data from Reference 4.

TABLE I-1. MAJOR CONTRIBUTORS TO AIR POLLUTION, ILLINOIS, ORBES PORTION

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%$†
Particulates	crushed stone	211	26	33	-45	34	-47	-4
	sintering	125	15					
	petroleum refining					4		
	electric-coal-old	121	15	4	-88	5	-87	3
	electric-coal-new			6		5		-39
	industrial-coal	62	8	5	-73	9	-55	49
	industrial-oil	17	2	6	28	8	43	11
	small rural grain handling	77	9					
	automobile travel	28	3	18	129	14	67	-31
	light truck			3				
Total net		823			-57		-60	-8
Sulfur oxides	petroleum refining-catalytic	48	4					
	petroleum refining-noncatalytic	195	15	7	-43	8	-44	-2

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[*] Only sectors contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater emissions under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the FTF scenarios.

TABLE I-1 (continued)

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{\text{FTF-BOM}}{\frac{\text{FTF+BOM}}{2}}\right]\%$[†]
	electric-coal-old	666	51	19	-57	20	-56	3
	electric-coal-new			33		21		-50
	industrial-coal	94	7	17	172	28	347	49
	industrial-oil	120	9	15	45	13	62	11
	residential-coal	45	4					
Total net		1315			12		8	4
Nitrogen oxides	petroleum refining-noncatalytic	28	4	6	131	6	126	-2
	electric-coal/oil-old	189	28	8	-52	9	-51	3
	electric-coal-new			20		16		-34
	industrial-coal	16	2	4	193	8	382	49
	industrial-oil	51	7	6	32	8	47	11
	industrial-natural gas	44	6			4	8	
	automobile travel	212	31	12	-36	10	-54	-31

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*Only sectors contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater emissions under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the FTF scenarios.

TABLE I-1 (continued)

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of PTF 2000 total*	Percent change	Percent difference $\left[\frac{\text{PTF-BOM}}{\frac{\text{PTF+BOM}}{2}}\right]\%^{\dagger}$
	light truck	47	6	12	178	9	93	-36
	heavy truck	52	7	13	175	10	91	-36
Total net		684			66		53	-12
Hydrocarbons	solvent-based paint	33	3	4	-40	5	-40	-.5
	rail			6				
	petroleum refining-noncatalytic	30	3					
	crude oil & petroleum storage	78	8	6	-60	7	-63	-9
	service stations	79	8	15	4	14	-25	-32
	automobile travel	393	41	21	-71	20	-79	-31
	light truck	174	18	24	-24	27	-34	-36
	heavy truck			8		7		-36
	personal truck	34	4			3	-59	
Total net		963			-44		-56	-25

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[*] Only sectors contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater emissions under the low-energy-growth (PTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the PTF scenarios.

TABLE I-2. MAJOR CONTRIBUTORS TO AIR POLLUTION, INDIANA (ORBES PORTION)

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total[*]	Percent of BOM 2000 total[*]	Percent change	Percent of FTF 2000 total[*]	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%$[†]
Particulates	asphalt			5		5		2
	crushed stone	113	14	25	-42	24	-44	-4
	sintering	299	37	6	-94	6	-95	-5
	electric-coal-old	137	17	6	-88	6	-87	3
	electric-coal-new			10		6		-41
	industrial-coal	60	8	8	-66	13	-44	49
	industrial-oil			1		1		11
	automobile travel			15		11		-31
	light truck			4				
Total net		797			-65		-64	3
Sulfur oxides	petroleum refining-noncatalytic	82	6	4	-43	5	-44	-2
	electric-coal-old	790	60	23	-57	42	-56	3
	electric-coal-new			50		27		-87

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[*] Only sectors contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater emissions under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the FTF scenarios.

TABLE I-2 (continued)

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{\text{FTF-BOM}}{\frac{\text{FTF+BOM}}{2}}\right]\%^{\dagger}$
	industrial coal	90	9	9	8	19	78	49
	industrial-oil	6	1	1	135	2	163	11
Total net		1054			14		3	-30
Nitrogen oxides	petroleum refining-noncatalytic			3				
	electric-coal-old	152	35	13	-31	16	-29	3
	electric-coal-new			33		33		-20
	industrial-coal	15	4	2	8	4	78	49
	industrial-oil	3	1	1	58	1	77	11
	industrial-natural gas	30	7			5	-9	
	automobile travel	118	27	11	-30	9	-49	-31
	light truck	29	7	12	237	10	134	-36
	heavy truck	32	8	14	233	12	131	-36
Total net		433			73		54	-18

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[*] Only sections contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater emissions under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the FTF scenarios.

TABLE I-2 (continued)

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%^{\dagger}$
Hydrocarbons	solvent-based paints	16	3			4	-38	
	solvent-based paints-industrial	21	4	5	-28	6	-28	-.7
	service stations	37	7	13	8	12	-22	-32
	automobile travel	219	43	22	-68	20	-77	-31
	light truck	107	21	31	-8	27	-36	-36
	heavy truck			10		9		-36
	personal truck	27	5	5	-38	5	-39	-.7
Total net		507			-37		-51	-25

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[*] Only sectors contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater emissions under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the FTF scenarios.

TABLE I-3. MAJOR CONTRIBUTORS TO AIR POLLUTION, KENTUCKY

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{\text{FTF-BOM}}{\frac{\text{FTF+BOM}}{2}}\right]\%$†
Particulates	asphalt					3		
	crushed stone	288	40	58	-19	58	-22	-4
	electric-coal-old	187	26	6	-88	6	-87	3
	electric-coal-new			8		5		-36
	industrial-coal	60	8	5	-68	8	-47	49
	coal-metallurgical cleaning	39	5					
	automobile travel			7		5		-31
Total net		729			-45		-47	-4
Sulfur oxides	petroleum refining-catalytic	23	4					
	petroleum refining-noncatalytic	21	4					

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*Only sectors contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

†A positive difference means greater emissions under the low-energy growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the FTF scenarios.

TABLE I-3 (continued)

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%^{\dagger}$
	electric-coal-old	348	64	19	-57	27	-56	3
	electric-coal-new			48		17		-115
	industrial-coal	90	17	17	49	38	146	49
	industrial-oil			5		7		11
	residential-coal	16	3					
Total net		547			43		6	-30
Nitrogen oxides	electric-coal-old	192	51	18	-31	22	-29	3
	electric-coal-new			38		32		-34
	industrial-coal	15	4	4	80	7	197	49
	industrial-oil			3		4		11

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[*] Only sectors contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater emissions under the low-energy growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the FTF scenarios.

TABLE I-3 (continued)

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%^{\dagger}$
	industrial-natural gas					5		
	automobile travel	84	22	8	-30	7#	-49	-31
	light truck	12	3	6	254	5#	146	-36
	heavy truck	13	4	6	250	5#	143	-36
Total net		379			93		64	-16
Hydrocarbons	ethylene dichloride	11	3					
	solvent-based paints			3		4		-.5
	solvent-based paints-industrial	17	5	6	-35	7	-35	-.7
	crude oil & petroleum storage	18	5	5	-47	5	-52	-9

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*Only sectors contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

†A positive difference means greater emissions under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the FTF scenarios.

#FTF 2000 emissions in these sectors estimated from other state figures.

TABLE I-3 (continued)

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%^{\dagger}$
	service stations	23	7	12	8	11	-22	-32
	automobile travel	156	45	25	-68	23	-77	-31
	light truck	44	13	21	-3	19	-33	-36
	heavy truck			7		6		-36
	personal truck	25	7	8	-38	7	-55	-32
Total net		346			-42		-54	-24

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[*] Only sectors contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater emissions under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the FTF scenarios.

TABLE I-4. MAJOR CONTRIBUTORS TO AIR POLLUTION, OHIO, ORBES PORTION

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%^{\dagger}$
Particulates	asphalt	74	4					
	structural clay products			4		4		-1
	lime	81	5					
	crushed stone	174	11	13	-47	13	-49	-4
	sintering	302	20					
	electric-coal-old	325	21	6	-88	6	-87	3
	electric-coal-new			8		6		-35
	industrial-coal	227	14	4	-87	7	-79	49
	industrial-oil			6		7		11
	automobile travel			11		8		-31
	coal transportation-conventional train	67	4	18	88	18	74	-8

*Only sectors contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

†A positive difference means greater emissions under the low-energy growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the FTF scenarios.

TABLE I-4 (continued)

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total[*]	Percent of BOM 2000 total[*]	Percent change	Percent of FTF 2000 total[*]	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%^{\dagger}$
	coal transportation-unit train			7		6		-8
	coal transportation-barge			3				
	coal transportation-other			3		3		-8
Total net		1577			-56		-59	-6
Sulfur oxides	petroleum refining-noncatalytic	98	4					
	electric-coal	1399	64	29	-57	28	-56	3
	electric-coal-new			35		29		-14
	industrial-coal	415	19	18	-11	27	47	49
	industrial-oil	81	4	8	107	8	132	11
Total net		2189			-6		4	8

[*] Only sectors contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater emissions under the low-energy growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the FTF scenarios.

TABLE I-4 (continued)

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%$†
Nitrogen oxides	electric-coal-old	261	40	12	-34	14	-29	3
	electric-coal-new			28		23		-34
	industrial-coal	70	11	5	17	10	92	49
	industrial-oil	33	5	6	160	7	191	11
	industrial-natural gas	45	7			4	21	
	automobile travel	208	32	11	-22	9	-43	-31
	light truck	53	8	11	219	9	121	-36
	heavy truck	59	9	12	215	9	119	-36
Total net		644			80		61	-11
Hydrocarbons	solvent-based paints	32	3	3	-39	4	-40	-.5
	solvent-based paints-industrial	38	4	4	-35	5	-35	-.7

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[*] Only sectors contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater emissions under the low-energy growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the FTF scenarios.

TABLE I-4 (continued)

Pollutant	Sector	Net 1972 emissions (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%^{\dagger}$
	service stations	76	8	13	5	12	-24	-32
	automobile travel	386	41	22	-65	21	-74	-31
	light truck	196	21	28	-13	25	-40	-36
	heavy truck			9		8		-36
	personal truck	38	4			4	-56	
Total net		952			-36		-50	-24

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[*] Only sectors contributing more than 3 percent of total emissions are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater emissions under the low-energy growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater emissions under the BOM scenarios relative to the FTF scenarios.

TABLE I-5. MAJOR CONTRIBUTORS TO WATER POLLUTION, ILLINOIS, ORBES PORTION

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{\text{FTF-BOM}}{\frac{\text{FTF+BOM}}{2}}\right]\%^{\dagger}$
BOD wastes	municipal sewage	13	18	44	-9	44	-9	
	high-processing packinghouse	5	7					
	sulfite pulp	10	15					
	building paper	5	7	4	-79	4	-80	-3
	industrial chemical	2	3					
	maleic anhydride	4	6					
	plastic materials & resins	4	6	7	-60	7	-60	-.5
	forest products & fisheries			8		8		-1
	canned & frozen seafood			4		4		
	canned & frozen fruits & vegetables			8		8		
Total net		69			-61			-.5

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[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE I-5 (continued)

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{\text{FTF-BOM}}{\frac{\text{FTF+BOM}}{2}}\right]\%$[†]
COD wastes	meat animals & other livestock	4	6					
	forest products & fisheries	5	8	21	89	22	87	-1
	industrial chemicals	7	12	9	-45	10	-45	-1
	dyes & dye intermediates	6	10	5	-64	6	-64	-.3
	maleic anhydride	9	14	16	-25	17	-26	-.5
	plastic materials & resins	9	14	17	-19	18	-19	-.5
	petroleum refining-noncatalytic	6	9	6	-59	6	-60	-2
	plasticizers	3	5	4	-47	4	-48	-.5
	poultry processing	2	3					
	dimethyl terephthalate	2	4					

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[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE I-5 (continued)

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%^{\dagger}$
	flat glass	2	4					
	electric-LWR			8				
Total net		64			-32		-37	-8
Total suspended solids (TSS)	coal-strip-mined			6		6		-8
	coal-metallurgical cleaning	163	8					
	coal-other processing	1828	86					
	electric-coal-old			6		6		3
	electric-coal-new			7		5		-34
	municipal sewage			44		45		
	canned & frozen fruits & vegetables			4		4		

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[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE I-5 (continued)

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%^{\dagger}$
	plastic materials & resins			9		9		-.5
Total net		2127			-99		-99	-2
Total dissolved solids (TDS)	coal-liquefaction					3		
	coal-underground	23	8	10	92	10	77	-9
	coal-strip-mined	88	32	38	83	38	69	-8
	coal-other processing	41	15					
	maleic anhydride	15	5	10	191	11	189	-.5
	electric-coal-old	41	15	3	-64	4	-63	3
	electric-coal-new			10		8		-34
	electric-LWR			4				
	industrial chemicals	8	3					

[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE I-5 (continued)

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{\text{FTF-BOM}}{\frac{\text{FTF+BOM}}{2}}\right]\%$ [†]
	dyes & dye intermediates			5		5		-.3
Total net		273			55		44	-7

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[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE I-6. MAJOR CONTRIBUTORS TO WATER POLLUTION, INDIANA, ORBES PORTION

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of PTF 2000 total*	Percent change	Percent difference $\left[\frac{PTF-BOM}{\frac{PTF+BOM}{2}}\right]\%^{\dagger}$
BOD wastes	meat animals & other livestock	3	6					
	municipal sewage	17	35	67	-42	68	-42	
	high-processing packinghouse	4	9					
	corn-wet milling	2	3	4	-62	4	-62	-.3
	citric acid	11	21					
	building paper	2	4			3	-79	
	plastic materials & resins	2	3	5	-58	5	-58	-.5
	canned & frozen fruits & vegetables			6		6		
Total net		50			-70		-70	-.4
COD wastes	meat animals & other livestock	10	22					

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*Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

†A positive difference means greater effluents under the low-energy-growth (PTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the PTF scenarios.

TABLE I-6 (continued)

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%^{\dagger}$
	citric acid	21	47	47	-72	50	-72	-.1
	plastic materials & resins	4	8	24	-16	25	-16	-.5
	petroleum refining-noncatalytic	2	6	8	-59	9	-60	-2
	forest products & fisheries	2	6					
	poultry processing	2	5					
	industrial chemicals	1	3	7	-42	7	-43	-1
	electric-LWR			5				
Total net		46			-73		-74	-6
Total suspended solids (TSS)	municipal sewage			44		46		

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[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE I-6 (continued)

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{\text{FTF-BOM}}{\frac{\text{FTF+BOM}}{2}}\right]\%$†
	coal-strip mined			9		9		-8
	coal-other processing	833	83					
	asphalt	69	7					
	electric-coal-old			9		10		3
	electric-coal-new			15		12		-31
	plastic materials & resins			5		6		-.5
Total net		1060			-98		-98	-5
Total dissolved solids (TDS)	coal-strip mined	81	9	9	100	8	85	-8
	citric acid	694	80	81	139	89	139	-.1
	electric-coal-old	48	6	1	-59	1	-58	3

*Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

†A positive difference means greater effluents under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE I-6 (continued)

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{\text{FTF-BOM}}{\frac{\text{FTF+BOM}}{2}}\right]\%^{\dagger}$
	electric-coal-new			4		3		-34
Total net		868			137			-10

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[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE I-7. MAJOR CONTRIBUTORS TO WATER POLLUTION, KENTUCKY

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{\text{FTF-BOM}}{\frac{\text{FTF+BOM}}{2}}\right]\%^{\dagger}$
BOD wastes	municipal sewage	13	34	57	-1	57	-1	
	high-processing packinghouse	2	6					
	alcoholic beverages	2	7	7	-43	7	-43	-.1
	plastic materials & resins	3	5	4	-75	4	-75	-.5
	plasticizers	1	3					
Total net		37			-41		-41	-.4
COD wastes	meat animals & other livestock	2	5					
	forest products & fisheries	2	5					
	woven fabric finishing-cotton, synthetic	1	4	5	-37	5	-37	-.2

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[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE I-7 (continued)

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\dfrac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%^{\dagger}$
	knit fabric finishing			6		3		-.1
	industrial chemicals	3	9	9	-48	9	-49	-1
	propylene oxide	4	12	8	-68	8	-69	-.5
	dye & dye intermediates			4		4		-.3
	plasticizers	2	6	6	-51	6	-51	-.5
	ethylene dichloride	1	4	4	-60	4	-61	-.6
	poultry processing	1	4					
	plastic materials & resins	4	12	20	-24	19	-25	-.5
	polyvinyl chloride	2	5	15	-29	14	-25	-3
	synthetic rubber	5	16	12	-63	12	-63	-.7
Total net		34			-52		-52	1

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[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE I-7 (continued)

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{\text{FTF-BOM}}{\frac{\text{FTF+BOM}}{2}}\right]\%^{\dagger}$
Total suspended solids (TSS)	municipal sewage			51		53		
	coal-strip mined			6		5		-9
	coal-other processing	1173	52					
	coal-metallurgical cleaning	971	43					
	electric-coal-old			10		10		3
	electric-coal-new			13		10		-31
	alcoholic beverages			4		5		-.1
	plastic materials & resins			5		5		-.5
Total net		2260			-99		-99	-4
Total dissolved solids (TDS)	coal-underground	61	24	34	97	33	75	-11

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[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE I-7 (continued)

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{\text{FTF-BOM}}{\frac{\text{FTF+BOM}}{2}}\right]\%^{\dagger}$
	coal-strip mined	46	19	34	162	34	139	-9
	coal-metallurgical cleaning	15	6					
	coal-other processing	27	11					
	electric-coal-old	61	25	7	-59	8	-58	3
	electric-coal-new			15		11		-34
Total net		248			42		31	-8

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[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE I-8. MAJOR CONTRIBUTORS TO WATER POLLUTION, OHIO, ORBES PORTION

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{\text{FTF-BOM}}{\frac{\text{FTF+BOM}}{2}}\right]\%^{\dagger}$
BOD wastes	municipal sewage	60	47	49	-61	49	-61	
	plastic materials & resins	10	8	8	-62	8	-62	-.5
	forest products & fisheries	7	6	26	66	26	64	-1
	citric acid	7	6					
	paper & paperboard mills			3		3		-.7
Total net		128			-63		-63	-.4
COD wastes	meat animals & other livestock	7	5					
	forest products & fisheries	34	25	56	55	56	53	-1
	acrylonitrile	8	6	4	-61	4	-61	-.4

[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE I-8 (continued)

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{\text{FTF-BOM}}{\frac{\text{FTF+BOM}}{2}}\right]\%^{\dagger}$
	citric acid	14	11	4	-75	4	-75	-.1
	dyes & dye intermediates	9	7	3	-66	3	-66	-.3
	plastic materials & resins	21	16	17	-24	17	-25	-.5
	synthetic rubber	8	6	3	-63	3	-63	-.7
	woven fabric finishing-cotton, synthetic	5	4					
	industrial chemicals	7	5	3	-56	3	-56	-1
Total net		134			-30		-31	-2
Total suspended solids (TSS)	municipal sewage	51	5	48	-50	49	-50	
	coal-other processing	673	65					
	asphalt	92	9					

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[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE I-8 (continued)

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{\text{FTF-BOM}}{\frac{\text{FTF+BOM}}{2}}\right]\%^{\dagger}$
	basic oxygen furnace-integral facility	46	4					
	electric-coal-old			6		7		3
	electric-coal-new			5		3		-31
	forest products & fisheries			8		8		-1
	coal-strip mined			4		4		-8
	plastic materials & resins			12		12		-.5
Total net		1037			-95		-95	-2
Total dissolved solids (TDS)	coal-strip mined	107	13	12	67	12	54	-8
	citric acid	460	54	68	115	70	115	-.1
	electric-coal-old	77	10	3	-59	3	-58	

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[*] Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

[†] A positive difference means greater effluents under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

TABLE I-8 (continued)

Pollutant	Sector	Net 1972 effluents (thousand tons)	Percent of 1972 total*	Percent of BOM 2000 total*	Percent change	Percent of FTF 2000 total*	Percent change	Percent difference $\left[\frac{FTF-BOM}{\frac{FTF+BOM}{2}}\right]\%^{\dagger}$
	electric-coal-new			5		4		-34
	steel	45	5					
	acrylonitrile					3		
Total net		854			69		65	-2

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*Only sectors contributing more than 3 percent of total effluents are presented. Therefore, the columns will not total 100 percent.

†A positive difference means greater effluents under the low-energy-growth (FTF) option relative to the high-energy-growth (BOM) option; a negative difference means greater effluents under the BOM scenarios relative to the FTF scenarios.

APPENDIX J

POPULATION ESTIMATES AND PROJECTIONS, ORBES REGION, 1975 and 2000

State portion	1975[*]		2000 projections					
	Population	Percent	Task 1[†]	Percent	Special study#	Percent	Kentucky Delphi Project[**]	Percent
Illinois	3,394,500	18.4	4,040,331	17.6	3,653,540	17.3	3,572,712	17.0
Indiana	4,100,500	22.3	5,122,200	22.2	4,582,594	21.7	4,616,192	22.0
Kentucky	3,396,000	18.4	4,406,794	19.1	4,428,826	21.0	4,361,992	20.8
Ohio	7,530,200	40.9	9,455,839[††]	41.1	8,469,472	40.1	8,426,950	40.2
Total ORBES region	18,421,200	100.0	23,026,164	100.0	21,134,432	100.0	20,977,046	100.0

[*] Current Population Reports. Series P-26, nos. 75-13, 75-14, 75-17, and 75-35. U.S. Department of Commerce, Bureau of the Census, Washington, D.C., 1976.

[†] See Reference 41.

[#] See Reference 12.

[**] See Reference 8.

[††] Calculated on the assumption that the ratio between the population of Ohio within the ORBES region and the total state population would remain constant between 1985 and 2000.

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